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THE MUSHROOM GROWERS'
ASSOCIATION

MGA BULLETIN

APRIL, 1958 · NUMBER 100

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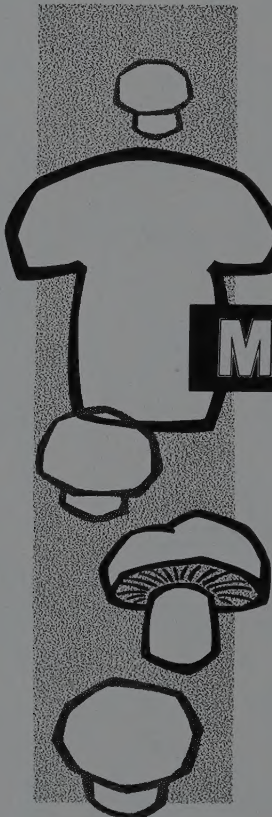
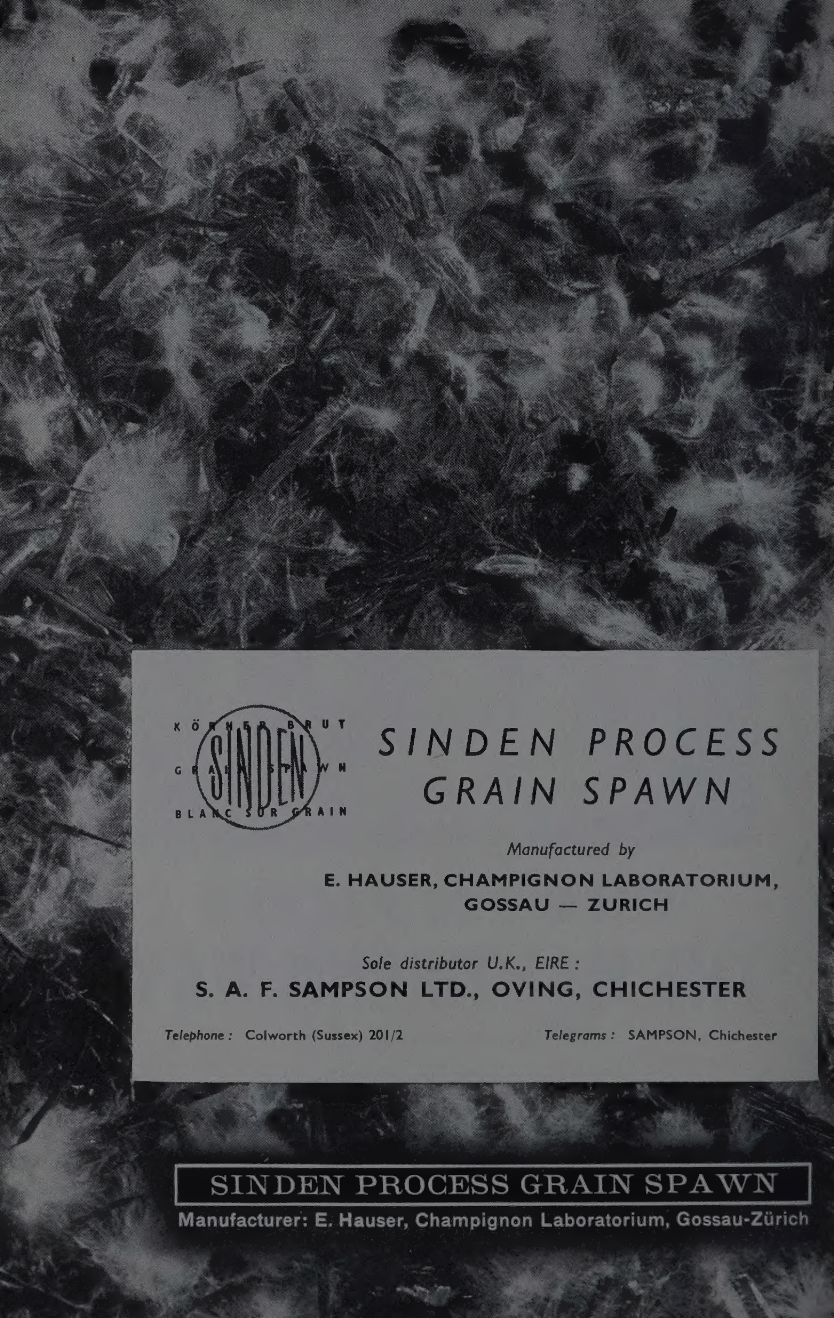
SOUTHPORT, 1957

Complete Papers presented at the MGA's Mushroom Developments Conference at Southport, England, on 2nd & 3rd October, 1957

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MGA BULLETIN

APRIL - 1958

NUMBER 100

EDITORIAL

OUR HUNDREDTH BULLETIN

In November, 1944, seven very individual individuals met in Peterborough and formally resolved to take what steps were required to organize the stupidly secretive Mushroom Industry in Great Britain. The austerity war-time lunch which followed was evidently depressing for, over coffee-of-sorts, the decision was informally rescinded "for fear of repercussions"; mushrooms were frowned upon in official circles in those days.

Fortunately for the Mushroom Industry, three of us refused to accept the informal hesitation, and it was left to Stanley Middlebrook and me to see what could be done.

Well, not exactly left to us; we took it upon ourselves! We enjoyed it all immensely, of course, and incidentally thought it was a Good Thing. The negotiations, the official approaches, the organization details, the secretarial work, were largely in my hands. Middlebrook provided the sounds off, many of the ideas, the music and refreshments, some of the fire and all the smoke. He did more ; he decided we must keep everyone informed of what was afoot and was Editor when *MGA Bulletin No. 1* was published in the autumn of 1945.

The *MGA Bulletin*, according to his Editorial, "is very largely *your* show. The Editor invites comments and suggestions so long as they bear on the essential maxim: Help yourself while helping others." The first issue contained News from MGA headquarters, Mutual Aid questions and answers, an article on Composting by Machine, a plea for new Textbooks, extracts from a Mushroom Grower's Diary "and other light matter." There were eight pages, and it was hoped to publish four times a year.

The Bulletin prospered, and in March, 1952, we had the courage to try publishing 36 pages **monthly.** That proved even more popular and now, in April, 1958, we have reached Number 100. We had thought of producing a nostalgic survey, written in the lightest vein; but the present state of the Industry isn't very funny, and we quickly decided that the occasion might be more *usefully* marked by the publication of all the papers presented last October at Southport, which has been described as "our most successful business conference to date."

But why am I introducing this Bulletin? Many growers to-day have forgotten the Midlands Group of Mushroom Growers, founded and guided by five strangely assorted characters of whom one died, one has retired from the struggle, one found other interests, and one appears to have disappeared in a cloud of smoke.

I alone remain on the Executive (as we go to press) to record that, in their time, in the end-of-war hiatus, those five growers recognised an opportunity and took it so determinedly that the Mushroom Industry in this country was galvanised into such activity in so many ways that growers and research scientists throughout the world were stimulated.

MGA Bulletin 100 marks the end of an era, and pinpoints the multitudinous problems which face us to-day. Future Bulletins will record how we conquer them *as we conquer them.*

Fred C. Atkins.

THE AGM AND LUNCH

A full report of the Annual General Meeting and Luncheon at the Connaught Rooms, London, on 18th March, will appear in the May issue. Mr. Frank Bleazard was elected Chairman, in succession to Mr. G. V. Allen, Mr. Raymond Thompson was elected Vice-Chairman, and elected or re-elected to the Executive Committee were Messrs. F. C. Atkins, R. Thompson, R. Pinkerton, G. Griffiths and E. A. Gook.

THE ANNUAL MEETING WAS ADJOURNED UNTIL THURSDAY, 17th APRIL, AT 2.30 p.m. PROMPT, AT AGRICULTURE HOUSE, KNIGHTSBRIDGE, LONDON.

ALL MEMBERS ARE URGED TO ATTEND.

POLYTHENE IN MUSHROOM GROWING

By FRANK W. ALLERTON
Chief Technical Adviser, Geo. Monro Ltd.

These middle years of the 20th Century will be recorded in the pages of history as the age when the physicist split the atom and the chemist synthesised complex polymers of simple organic molecules to give the world plastic materials of almost unlimited versatility.

The former enterprise is already recognised as a distinctly mixed blessing; the latter a benefit to mankind which extends its virtues to every aspect of human endeavour.

The horticultural industry has not been slow to recognise and to apply the advantages offered by plastics in one form and another and in the form of thin, light transparent films, these new materials have already achieved an important place in both culture and marketing.

In this highly specialised corner of the Industry the mushroom grower is, I would think, more vitally concerned with achieving close control of atmospheric conditions than even his glasshouse brethren. The tomato will produce an economic crop under a surprisingly wide range of conditions; the mushroom, even in my limited experience, constitutes a more sensitive recorder of microclimate than the finest of thermometers and hygrometers.

Be that as it may, a material which can be provided as a film only 1½ thousandths of an inch thick, which is incredibly light and flexible, which is impervious to, and unaffected by, moisture and micro-organisms and which has a life measured in many months when exposed to full sunlight, cannot fail to present attractions to the mushroom grower.

Such are the properties of the polythene film and to a large extent of PVC film and certain others. As, however, my own personal experience is limited to polythene I propose to restrict my remarks to that specific type of film.

As might be anticipated from its insubstantial nature, 1½ thousandths film has virtually no intrinsic insulating properties. It allows both solar and longer wave heat radiations to pass readily and in the latter respect is inferior to glass as a heat-retaining barrier.

Indirectly, however, it serves as an excellent insulator as, when tightly secured in overlapping sheets to glasshouse glazing bars or similar structural members, it traps a layer or sheath of more or less still air. It is this layer of air which provides the insulation but it is the polythene sheeting which pockets the air where it is wanted. In practice it is found that the air gap should not be less than 1 inch or more than 3 inches for maximum insulating efficiency.

Fixing, though requiring some experience and dexterity for efficient execution, involves nothing more difficult than tacking the sheets to the supporting framework with a one-handed stapler. Desirably the supports should not be more that 24 inches apart and, whether the film

is run horizontally or vertically, care should be taken to avoid folds and rucks. This is most important as folds present drip-points for condensed moisture which would otherwise flow down to the floor. Equally, a smooth, uncreased surface makes the most of the water-repellent, free rinsing nature of the film.

These properties, coupled with that of impermeability to water and water vapour, would seem to present polythene film as a highly desirable material for the innermost lining of mushroom sheds.

While the film has undoubted advantages in this direction it should at this stage be pointed out that a structure completely and efficiently lined with polythene is completely devoid of air circulation and rapidly assumes a dead, saturated atmosphere. It may be unnecessary to point out that such an atmosphere is scarcely conducive to satisfactory cropping! In all seriousness, however, I would emphasise that the draught excluding and humidity-promoting properties of polythene film should be exploited with a close eye upon the stagnation effects which are inseparable from its general use. It should be looked upon as a valuable means of controlling draughts and extraneous moisture and heat losses. In no way can it replace efficient heating or direct moisture control and its use demands that the ventilating technique be even more critical than before.

In the instance of catch crops of mushrooms in glasshouses, a system of culture for long practised widely in the Worthing area, and more recently in the Lea Valley, polythene sheeting has more obvious virtues than in special mushroom structures.

Thus, all but the newest of glasshouses are relatively draughty structures and are almost impossible to raise to peak heat temperatures for the required period, even in the Autumn months. Polythene lining, with the film either draped over wires and secured with spring pegs or stapled direct to the glazing bars, provides valuable insulation. It is essential, however, that the ventilators be lined separately so that they can be opened as required, while the installation of fans is highly desirable to provide a means of increased ventilation as and when needed. Lofty houses can be reduced in operative volume by providing a false ceiling of polythene film but considerable condensation must be anticipated and this procedure is best restricted to the peak heating or end-of-crop burning out periods when elevation of temperature is the primary consideration.

Polythene is now readily obtainable as black, virtually opaque, film in the same 1½ thousandths gauge. This would appear to have obvious attractions for glasshouse lining, as both insulation and light exclusion are achieved at the same time. From late September onwards this black film can certainly be used to advantage by catch-crop growers, but when the sun is hot the absorption and re-radiation of heat from the film causes a gradual build-up of undesirably high temperatures. In extreme cases sagging and even partial fusion of black film has occurred.

Growers starting off catch-cropping in August and wishing to use black film to avoid the need for external thatching or other light-and-heat-excluding techniques would be well advised to shade the glasshouses heavily to break the direct rays of the sun.

The standard gauge sheeting, either clear or black, can be used to good purpose for isolating floor beds from the underlying soil of the house and I have encountered no objections to this practice. To provide inside curtains over windward doorways is another obvious use of this versatile film.

I have seen most effective use made of this thin film as a windbreak around the sides and ends of composting sheds and it might even be wrapped around the sides of heaps being prepared in exposed situations. Covering of heaps during composting would obviously be undesirable, however, in view of the saturation of the top of the heap by the condensed moisture and the reduction of air-penetration.

An interesting and practical use for polythene film is that of lining shelves and trays which, despite treatment, are suspect of carrying disease or eelworm. The "breathing" properties of the film has some virtue in this instance.

For more mechanically-resistant and permanent wind screens the thicker 0.005 inch thick film has obvious advantages.

The fact that the various gauges of film are available also in tubular form has led to apparatus being devised for blowing unheated or warm air through perforated polythene trunking.

The well-known "Autovent" apparatus is based on this principle and already it is proving most useful for supplementing the ventilation in structures devoted to tray culture.

It is not difficult to visualise the adaption of this apparatus for virtually closed-circuit ventilation in highly specialised structures of the future.

Many other uses for these versatile films will doubtless be developed to meet specific requirements but these brief notes may be sufficient to point the way to their practical use on the mushroom farm.

DISCUSSION:

Although polythene is useful for surrounding the heap on its exposed sides, actual *covering* of the heap should only be resorted to when heavy rain would do more damage than the temporary exclusion of air. Condensation could be excessive.

In some mushroom houses the flushes are incredibly large. Could it be that the cultivated mushroom is being pushed too far, and thus is being taken within a region where its **susceptibility to disorders** is increased? If this were so it could then furnish an explanation for many of the disorders now being experienced.

Martin D. Austin in *Commercial Grower*, February 21/58.

MUSHROOM COMPOSTS BASED ON PEAT AND OTHER MATERIALS

Dr. WERNER ARNOLD
Director of Mushroom Research, Dieskau, East Germany

There is no crop which depends so much on the compost as the mushroom. For many years horse manure has been the foundation of mushroom composts and, even to-day, mushroom growers in general believe that only horse manure is really satisfactory. If this were so, expansion of the mushroom industry would depend on how much horse manure is available and upon its quality; and the situation to-day is that there are fewer and fewer horses as machinery takes over, while the demand for their manure is increasing. The deduction is that it is possible to grow more mushrooms only by a departure from horse-manure.

Once upon a time no-one considered there were any difficulties involved in the use of horse manure, but growers were sometimes very disappointed with their crops, and they began to realise that there *were* risks with manure, particularly in large-scale growing. The content of horse manure differs widely, as analyses reveal, depending on the feed, how hard the horses are worked, environmental factors, and so on. Just looking at the manure cannot tell us what treatment is required to turn it into a first-class mushroom compost.

We all know the problems which beset users of racing-stable manure, or of manure from animal hospitals. A lot of green food in the diet means a poor compost; and much of course depends on the straw used for bedding-down the horses.

It is a matter of fact that the quality of the manure and the bedding material cannot be adequately judged by estimating the relative proportion of droppings to straw. Other means of assessing its value are needed. Nevertheless, despite all these difficulties and dangers, growers in general continue to rely on horse manure rather than follow the example of Agriculture, which has progressed enormously by adopting artificial manures.

Let us consider these artificial manures for a moment, first because they were invented in Britain and also because they are so rarely used in mushroom culture.

The agricultural research station at Rothamsted evolved a synthetic farmyard manure known as Adco. Activators are added to an organic base which is composted, and a product similar to horse-manure is the result. Adco " M " is a variant often used by mushroom growers to supply N, P, K and Ca, but in practice it is little used on its own for synthetic compost.

In 1891 Herfurth patented a synthetic compost process. He mixed short straw and peat with horse manure, and every three days throughout the entire cropping period he watered the beds with a rainwater solution of sodium nitrate, ammonium sulphate and potassium phosphate. But the idea was never adopted by practical growers.

We know from Cayley's research that the food requirements of the wild mushroom differ from those of the cultivated mushroom. But every cultivated mushroom does not have exactly the same nutritional requirements. In our research, and in Hungary, it has been proved that the white strains make different demands on the substrate than do the brown strains; and analyses of the ash of the fruiting bodies show how wide are the differences in N, P and K.

In order to use synthetic composts we must know the needs of the mushroom which is to grow in it, and these needs can be discovered by analysis of the mushroom and of the compost. Stoller was quite right when he analysed both the spent compost and the mushrooms it had produced. Such analyses vary considerably, but there is always observable a definite tendency: The most important nutrients are potassium, phosphorus, chalk and *readily available* nitrogen.

Stoller based his recommendations on this knowledge, which is similar to that long used in agricultural research. He expressed the required nutrients in N : P : K ratio, and went so far as to advance the theory that this ratio should be 2 : 1 : 2.7 in the compost and 2.7 : 1 : 1.8 in the mushroom. This hypothesis has been confirmed by our own researches.

Edwards later used this method to develop the MRA formula for synthetic compost which Noble Mushrooms Ltd. has followed so successfully. Other growers, on the other hand, are using synthetic composts founded on an arbitrary basis, and they too have very good crops!

It is not only the N : P : K ratio which is important; other factors play a significant role. These three major nutrients are essential, as in all plant biology; but alone they are insufficient. In the foreground, without any doubt, is the nitrogen. Nitrogen as ammonium salts and amino acids is easily and completely assimilated; as amides (asparagine) it is less readily available, and still less readily as urea.

Lamber experimented with many sources of nitrogen. He had his best crops when he used bried blood. Urea alone was good, but results were better when it was used with dried blood. Stoller researched systematically into 17 nitrogen sources, and noted that crops were higher when he used organic rather than inorganic sources. He found ammonium sulphate unsatisfactory, as subsequent mycelial growth was retarded by the evolution of ammonia. So he recommended the addition to ammonium sulphate of cheese whey and milled maize.

It is worth stating that maize is preferable as a source of N; but we must add that maize, besides nitrogen, contains calcium, magnesium, sulphur, potassium, silicon and chlorine—and the amount of magnesium is very high. Almost the same elements are to be found in *Helianthus annuus*, and this enables us to use the stem of this plant as a base for mushroom composts.

Edwards recognised that ground hoof-and-horn had the same influence as dried blood. In our investigations we too used this material with satisfactory results. Edwards also worked with dried blood, which he found to be a better N source than inorganic materials; but he did not attempt to retard the evolution of ammonia by adding whey and

maize as Stoller had suggested. His unsatisfactory results with calcium nitrate may have been due to the inability of the micro-organisms to change the calcium nitrate to ammonia in long-straw stacks.

Sinden, and later Edwards, tried additions of calcium cyanamide, but neither had much success with it. Stoller's researches with liquorice roots, myrobolam nuts, etc., should also be mentioned. Treschow worked successfully with pine needles, and some used Milorganit, a sewerage product, as a source of N. Treschow advocated the use of nitrates as the N source.

It is our opinion that organic materials are preferable to inorganic, and we have tried a great many—though without getting very far.

Phosphoric acid is an important ingredient of the mycelium and of the fruiting body, and must be important in the compost. Many experiments have demonstrated that there is sufficient phosphoric acid in the organic materials we are using in synthetic composts, so that no addition is necessary. Stoller as well as Edwards, however, recommended the addition of some superphosphate at the end of the composting process.

Hasenohrl and Zellner noted that the mushroom contained more potassium than calcium, and Stoller demonstrated that potassium exerted a significant influence on the development of the sporophores.

But calcium is not without importance to normal development. In 1908 Schuller mentioned the necessity of adding gypsum (calcium sulphate), and to-day there is probably not a single grower who does not add gypsum or some form of calcium to his composts.

Little notice is taken of the mushroom's demand for magnesium, but we do know that some fungi can tolerate large amounts without effect, while others make increased growth, as Starc proved.

Modern research has revealed that, besides the main nutrients (N, P, K and Ca), certain trace elements are also necessary. Stoller's recommendations of manganese, iron, aluminium, chromium, copper, boron, zinc, bromine and iodine. Edwards added molybdenum; and Niemann, Gerlach and Rath obtained a 25% increase in yield by adding copper, manganese and boron.

Much work in this field has yet to be done, and it might be suggested that one of the advantages of blood is that it is a source of trace elements.

We ourselves have carried out trials with the fertilizer mixture " Sl ", a proprietary product here for hydroponic cultures. The results were encouraging, if only that they suggested improvements were necessary.

The vitamin aspect is interesting. Treschow in 1944 demonstrated that mushroom mycelium would not grow in submerged culture until biotin (vitamin H) and thiamin (vitamin B_1) were added. He also found that yields increased when thiamin was added to the compost just before spawning. Hoffmann obtained a 15% increase by adding thiamin to the surface of the compost just before casing.

Stoller, however, and Lambert and Ayers too, found no increase in yield from the use of vitamins. We had similar results, although the rate of mycelial growth was speeded up.

We have made many trials with sawdust and wood shavings. Rempe at Essen-Bredeney used sawdust for his composts, and its low price and the ease of handling were attractive. He found that fermentation was improved if he mixed even proportions of sawdust and straw. Rempe's work was very promising, and it is a pity it had to be abandoned.

In the time available to-day I have been able to mention only some of the researches and observations on synthetic composts, but it should be easier now to develop a synthetic compost for mushrooms. Such a compost:

(*a*) Must be uniform in composition.

(*b*) Must have all its nutrient in optimum relation, including ancillary or accessory nutrients about which we know almost nothing as yet.

(*c*) Must be of the most desirable physical quality.

Synthetic composts to date are based largely on empirical knowledge, and empiricism must be rejected from true scientific research.

In our researches on synthetic composts based on straw we put the straw through a machine which breaks and aerates it, cutting it into half-inch lengths or even into chaff if we wish. Straw which has been chopped is easier to handle and the composting period is reduced. But it is very important that the fibrous structures remain, or aeration will be seriously affected. It is even more important when peat is added to the compost, because some peat has very little fibrous structure.

Following the successful use of peat in hydroponics and garden soils, we have been trying peat in synthetic mushroom composts. We noticed at once that the quality of the peat differed with its age and depth. Young peats which retain some fibrous structure are preferred.

It is important to realise that peat is a useful source of trace elements.

It is a disadvantage that the spawn grows very thickly on the peat parts of the compost because, during cropping, the mycelial strands can easily be disturbed.

But it should be stated that we believe peat to be a very promising base for synthetic compost. We are going to build a new mushroom farm near a peat factory in Mecklenburg, in North Germany, and **there we shall work only with peat composts.**

My original paper could not be translated in full in time for this Conference to-day, and there are a number of omissions in the translation which I regret but for which I must accept responsibility. Yet I hope I have shown you how many problems still remain to be solved. It is also, in my opinion, desirable and necessary that research workers should collaborate as far as possible; at Dieskau we have had few contacts with your workers.

Every day we meet with new problems, and my recent exchanges of views with Mr. Fred. Atkins have been valuable to us. I want to say Thank You to him and also to express my appreciation to you for so kindly inviting me to visit England and your Conference.

I would be very pleased at any time if members of the MGA would visit me at Dieskau. In extending to you this invitation, I have the support of my Government.

To-day, it is possible only to show you some pictures, but they will, I hope, persuade you that we are working earnestly on the many problems which face us all.

DISCUSSION:

Comparable results had been obtained from horse-manure and from composts to which peat, young peat mixed with straw and, best of all, flax residue had been added. Yields were about 0·8 lb./ft.

The biggest growers in East Germany had about 30,000 sq. ft., but there were many who grew mushrooms as a catch crop.

The brown-type mushroom is not popular with most buyers in the London area. **Brown mushrooms** are heavier than white, so the housewife doesn't get so many in her quarter-pound. But when they are sold really cheap and can be sold in half-pounds at a reasonable price they go out quite well. This week the brown sold at between 2s. and 2s. 6d. per lb. *Grower*, February 22/58.

Please attend the Adjourned

ANNUAL MEETING

at

AGRICULTURE HOUSE LONDON

on

THURSDAY, 17th APRIL

PROBLEMS FACING THE BEGINNER

By **Fred. C. Atkins**

The initial problem—whether or not to be a mushroom grower—has already been resolved by the beginner. He has made up his mind to try to grow mushrooms on a commercial scale. Established growers to-day must wonder how he came to that decision. Obviously he is mad—or mad enough to pass unnoticed in a crowd of mushroom growers. But what on earth persuaded him that mushrooms were a crop in which complete ignorance and inadequate capital gave promise of Success? Apart from irresponsible advertising, I mean. Let us consider some of the implications:

1. Mushrooms are grown from **spawn.** The making of spawn is not a difficult process; the essential details were published over 50 years ago. Since most spawn makers are human, there are from time to time instances of carelessness in manufacture, and quality varies; and sometime strains are changed. Yet from the most surprising quarters sometimes comes the cry: " Don't blame the spawn!"

The primary reason why so few growers or groups of growers make their own spawn is not that it is at all complicated, but because they realise that the maintenance and improvement of strains are highly complex problems which no-one fully understands. Indeed, there has been some serious talk in Europe recently of the need for an international spawn-research centre. Such a desirable adjunct may never materialise, on financial grounds only; and in the meantime the more serious spawn plants carry on their own private research, realising that until more fundamental data are available they must expect occasional inconsistencies in the behaviour of their strains, and complaints from choleric growers. Spawns are not invariably blameless—I cannot understand why the makers are so ultra-sensitive about the fact—but in the great majority of cases where the spawn is blamed the grower is probably at fault.

2. Mushrooms are grown from spawn planted in **compost.** Our growing medium is the least consistent material we use, and may be one-third responsible for our crop variations.

We can take horse-manure or synthetic compost, mix it, chop it, wet it, and do all the composting in the house. We can compost it entirely outside, with a short, final " conditioning " in the house. We can split the job into two, and do one phase outside and the other inside. We can, in fact, adopt a variety of techniques with a marvellous range of sizes and shapes of stacks and intervals between turns. The resulting yields will differ, but probably no more than if we attempt to follow exactly the same procedure every time.

No-one, least of all the grower, knows exactly what goes on in the compost heap; but having decided which method we shall use, we can hope in time to learn more about it and so reduce the variations between one stack and the next. A standard procedure should be aimed at, though it is bound to be frustrating, because the material varies enormously, especially the straw, and because the changing seasons profoundly influence the composting process.

To-day the tendency seems to be to compost in the open so that as much air as possible can get into the stack. But there is already sufficient evidence to persuade me that the development of composting in a controlled environment is awaiting only the introduction of that kind of capital.

3. Mushrooms are grown from spawn planted in compost which is covered with a layer of comparatively inert material referred to as the **casing.** Within the past five years practically every grower in Britain has changed from a variety of casing soils to a variety of peats. (Having revolutionized the Industry by demonstrating the value of peat, thereby unwittingly removing the brake on expansion, the industry's own research station was promptly abandoned. But that is by the way).

We know next to nothing about the function of the casing layer and less about the causes of fruiting. We know that mushroom mycelium favours a pH between 7 and 8, and that an unfavourable environment encourages fructification; so we see to it that our casing is neutral or a shade above it ! We know that mycelium loves moist conditions, so we keep the casing as damp as we dare! And so on. In fact, we do our best to discourage pin-heading, yet such is our ignorance that most of us have so far managed to stay in business.

4. Mushrooms are grown from spawn in cased compost placed in a highly variable climatic **environment.** There is little doubt that, if we knew precisely the ideal environment at respective stages in the mushroom cycle, it would be economic to build air-conditioned houses; but I know of no comprehensive study of this nature now in progress in Britain which is likely to be published. So the majority of us allow the force and direction and temperature and humidity of the wind to govern very largely the weight of our crop and its quality. One of the few remaining virtues of the Tray System is that it compels a grower to resort to fans !

5. Mushrooms grown from spawn in cased compost in an uncontrolled environment are mostly **offered for sale** on the fresh market where prices collapse if a spell of warm weather coincides with heavy flushing.

As a nation we are the third largest producers of mushrooms in the world. Long ago France and the United States resorted to canning and processing to help stabilize a vulnerable economy; yet the quantity we conserve is almost negligible—perhaps because we hesitate to put ourselves at the mercy of the canners. But probably five million pounds were sold at less than cost this summer, and some could not be sold at all.

It seems to be of singular importance to the marketing of our product that we remove the lowest grades and all stalks from the fresh market, and process them in some way. The danger lies in the possibility that, having accustomed the consumer to conserved mushrooms, we may open the door to a flood of imports. European Free Trade could be very serious for the Mushroom Industry here, for I doubt if any other country's costs of production are as high as ours.

6. The Industry has benefited and will continue to benefit from the existence of its own **organization:** beginners can take the word of pre-war growers on that point, and all should join the MGA at the outset of their hazardous career. Begun as a mutual-aid group, the MGA seemed at one time to be developing into a social club, but it is now very properly functioning as a trade protection society.

Incidentally, there has recently been a noticeable change in the general picture. Growers are becoming more reticent, thinking it stupid to share experiences too openly with their competitors. This tendency is not confined to the short-sighted; some of our more intelligent growers fully realise that the preserving of our little secrets means the perpetuation of our abysmal ignorance, but feel that anything which at this moment would increase the output of mushrooms from every farm would merely depress prices further.

7. This year, too, has seen an intensified rate of **expansion.** I am the last person to criticize another's wish to build more houses, but the net result of Supply increasing faster than Demand is the necessity to work harder for the same or a lower reward.

One cynic suggested this would do us all good, going so far as to say that, if it were in his power, he would force prices down deliberately to rid the Industry of the less efficient growers. While I do not accept this ruthless philosophy, lower prices certainly stimulate the search for increased efficiency, and we have in general been far too complacent.

8. What of **the future?** I am much concerned over the conclusion some have reached that the days of the small grower are numbered. I do not know if it is an accurate assessment, but it may well be. Certainly the newest ideas demand a great deal more money than used to be required. And if new farms need a heavy investment, what is the impact going to be should a financier or a wealthy industrialist enter our under-capitalised ranks?

Probably he would first approach the British Association of Consultants, of which I am a member. Probably he would be referred to me. Probably my advice would be as follows:

(*a*) A private spawn plant would obviously be economically desirable on any farm whose annual spawn bill approaches £2,000. Alongside, research would be started on strains designed for his way of growing.

(*b*) I would not expect a businessman to tolerate for long our present composting confusion and its susceptibility to the elements, and I would advise experimentation with rack-and-pinion and/or chimney devices already patented and published.

(*c*) I would counsel the building of cropping houses in which there was a considerable degree of environmental control.

(*d*) I would suggest that all but the best quality mushrooms were processed on the site in some way and, if possible, exported.

That is the kind of advice I would offer a newcomer able to afford these dreams—and my fees ! If his bank balance were too modest I would say, quite simply, Don't !

The problems facing the beginner are those which face all growers, large and small—but especially the small ones—and they are epitomised in one word: Survival. Newcomers cannot be expected to realise this fact; established growers should no longer ignore it.

THE 'OPEN STACK' TRAY SYSTEM

ROBT. G. DARLINGTON
W. Darlington & Sons Ltd.

Although the tray or two zone system is undoubtedly a step forward from the older shelf bed method, it does create many problems for the grower. To obtain the fullest advantage from the tray system it must be operated intensively and this means that a fixed programme must be adhered to, often at the expense of cultural requirements. Further, although lending itself more readily to mechanisation, the elimination of manhandling of the trays themselves is only possible to a limited extent on the scale of operations undertaken by most growers.

There are also cultural disadvantages. Perhaps the greatest is the need for more efficient air movement due to the baffling effect of open brickwork stacking. Other more minor disadvantages must each contribute to reduced overall yields and perhaps to a lowering of quality. There is a greater difficulty in correct watering than with continuous beds. Workers tend to skimp their tasks particularly with the more inaccessible trays.

Due to these difficulties, if not wholly then at least in part, mushrooms produced in trays are rarely the equal of those from shelf or flat beds either in quality or yield over a comparable period of cropping.

At the Experimental Farm at Angmering a compromise has been reached between the shelf bed and tray systems which has helped us to overcome many of these problems and yet retain most of the advantages which the orthodox tray system can offer.

This compromise, which we call the " open stack " tray system is based on the use of trays rather larger in area than is usual and fitted with corner posts to separate them by 7—8 inches when stacked. When assembled in sets 5 or 6 high, they become virtually sections of shelf beds of about 65 square feet of cropping area which can be easily moved by one man with a fork lift truck. When stacked for cropping they form continuous beds 4 ft. wide and of any length.

The idea of the " open stack " method was first originated by Mr. C. King of Heather Farm, Woking, who has now converted his entire farm to this system. With his help, and some modifications based upon two years of experimental work, we have now installed this system at Angmering.

At first the use of " open stack " trays followed almost identical lines to those employed for the orthodox tray or two zone system. On filling, the trays were taken from compost shed to pasteurisation room and after cooling were spawned and placed in a spawn running room. They were cased en route to a cropping room and of course finally emptied and returned to the compost shed for cleaning and refilling. All these operations were carried out with the aid of the fork lift and from the time the empty trays were stacked for filling until the spent compost was tipped out of them, no manhandling whatsoever was

necessary. With the orthodox tray system the trays must be manhandled several times whatever mechanical aid is available, namely when turning over for spawning, and stacking for cropping and unstacking for emptying. All this manhandling was eliminated and we believe this, and the ease of movement, to be worth a saving of at least 25% of our labour costs from the time of filling onwards.

In the cropping rooms the open stack trays have proved themselves from the start. The size and quality of the mushrooms is definitely superior than from trays stacked in open brickwork fashion. They are easier to manage during the cropping period, watering, packing, etc. being more comparable to a fairly narrow shelf bed.

At this point it is of interest to pause and consider how far we had come towards achieving our original object, that of getting the best from two worlds—trays and shelves. Mechanisation was possible, to an even greater extent than with ordinary trays; we were able to make maximum use of our cropping rooms by the two zone system (one heat room was serving 10 cropping units) and yet we had cropping conditions, access to the beds and other advantages normally obtained only with shelf bed growing. There seemed to be no reason, given equivalent depth of compost, why shelf bed yield should not be achieved.

Although we had had higher yields from " open stack " trays than from the ordinary trays against which they were compared, we were not sure that a greater depth of compost had not contributed to this increase. We had never subscribed to the view, commonly held, that the depth of compost should be proportional to the cropping period and that a greater depth of compost than, say, five inches was of no value unless an extended cropping period was envisaged.

We considered the economics of this question. We were accustomed to filling 5 inches of compost—often rather less—for a 6 week cropping period and were averaging $1\frac{1}{2}$ lb. per sq. ft. What would an additional inch, or even two inches, be worth? Would the benefit be worth the cost? A series of trials suggest that, for a six week cropping period at least under our conditions and our methods of growing, an extra depth of $1\frac{1}{2}$ inches is worth a minimum of $\frac{1}{4}$ lb. square foot. This increase, even with a net return of 3/- lb., makes the additional cost well worth while.

Another factor which has influenced our method of application of the open stack principle is the influence shown by replicated trials of the rate and method of spawning. Some time previously a series of trials has shown increased yields by the use of both grain and manure spawn and many growers now adopt this practice regularly. This led us to the principle of " Through spawning "—that is the distribution of the spawn, all grain in this case, right through the compost, instead of broadcasting it over the surface, or ruffling it into the top layers.

The encouraging results from this method may be due to any of a number of reasons and we hope eventually to evaluate at least some of them. Among the more likely are the aeration given to the compost

during mixing and the more rapid permeation of the compost with spawn resulting from the heavier inoculation and the more intimate mixture.

In any event, the use of open stack trays has now been modified to enable both these practices, that of increased depth of compost and through spawning, to be adopted as standard practice. In all results so far increased yields have been recorded and these vary from 20—80%.

A study of the records and results of these trials shows two very interesting possibilities. In the simple through spawning trials, where no increase in depth of compost was allowed, the higher the yield from the control of normally spawned trays, the smaller the increase. This suggested to us that the better the compost, the smaller the difference which might be expected and practical observation appeared to confirm this theory.

On the other hand, with the simple trials of increased depth of compost, the converse appeared probable. In other words, the greatest benefit from increased depth of compost could only be expected from really first-class material.

The implications of these two possibilities are obvious. On the one hand it seems possible to provide against a poor compost by a heavy inoculation whilst, on the other, we ensure that if our compost is good we will derive the maximum benefit in terms of pounds per square foot.

SUMMARY

The use of the ' open stack ' method of production is more economical in labour costs than the orthodox tray system and provides better cultural and working conditions during the cropping period.

The initial capital cost of the component trays is high but when expressed as a cost per square foot per crop is lower than that of fish trays and approximately equal to that of purpose built trays.

The use of a greater depth of compost than is normal is made possible with this system and seems economically sound even with relatively short cropping periods. Higher average yields have also been achieved by " through spawning."

DISCUSSION:

We have finally decided on trays 6 inches deep inside.

We find that the quality of the mushrooms deteriorates if the surface of the casing is below the level of the edges of the tray. I think it is most important to avoid the stagnant pockets which result if the casing is much below the edges of the tray.

While we have not evaluated the respective yields, the mushrooms grown under open-stack conditions are more chunky, hug the beds, and cluster better than when open brickwork layout is employed.

Spawn is scattered by hand over the compost after pasteurization, and the compost is then emptied into a modified turning machine, and tamped into open-stack trays.

Even though the increased depth of tray, and the increased gap between, do reduce the number of trays high, this loss of area can be compensated for by increasing the width of the trays.

AIR AND THE MUSHROOM

T. G. FIGGIS

This paper has a very simple title—its simplicity then promptly finishes. We know the mushroom is one of the most difficult crops to cultivate consistently, and that it is highly sensitive to its environment. Nevertheless constant experiment aided by science has greatly improved our commercial growing efficiency until, in 1957, the really good grower with suitable equipment can hope for 300 to 400 pounds of mushrooms per ton of boosted horse manure. On trays he will look for $1\frac{1}{2}/2$ lb. per sq. ft. in 6-7 weeks, filling at about 200 sq. ft. per ton. On shelves he may fill at about 120 sq. ft. per ton and hope for $2\frac{1}{2}/3\frac{1}{4}$ lb. in 9 to 11 weeks.

If he cannot achieve these outputs, at least when everything goes to plan, there is something wrong somewhere.

Air, of course, plays a part in almost every stage of mushroom cultivation, including composting, and also vitally influences each aspect of the mushroom environment. This evening there is less than half an hour to cover this tremendous subject.

It is impossible to give you chapter and verse for each point covered, and it will not be possible to discuss in detail the various ways of air conditioning mushroom houses. However, I do want to describe some basic principles and I hope some of the information given in this paper will help you to give your mushrooms the kind of air they really want.

Mushroom growers are principally interested in the temperature, humidity, purity and movement of air. How do these four factors affect the mushroom environment at all stages of cultivation? This is the 64,000 question.

Before considering it we should "go back to school" and get some understanding of air and its physical properties.

Definitions and Physical Properties

Temperature. There are three kinds of temperature, dry-bulb, wet-bulb and dew-point. Not everyone understands the meaning of wet-bulb, or appreciates its value. Briefly it is the temperature registered by a thermometer bulb covered by a wetted wick. It is, in fact, the temperature which may be reached by any wetted substance over which air moves—e.g. the casing layer, or the floor of the mushroom house, if it has been watered, will try to reach the wet-bulb temperature of the air above it. Wet-bulb temperature is important for several reasons. It is an easy method of obtaining the relative humidity. It also tells us the dew-point temperature (i.e. that temperature at which air is at 100% relative humidity and carries maximum moisture). In turn, the dew-point is directly related to the vapour pressure of the air and the amount of moisture in it—usually measured in grains per cubic foot (7,000 grains = 1lb.).

As a practical illustration, the air in a mushroom shed may have a dew-point of 54° F. In Winter the outside dew-point will be much lower—perhaps 40° F. or even below freezing point. This means that the inside air moisture, or vapour pressure, is much higher than outside.

What is happening? All this extra moisture is evaporated from the beds unless some method of humidification is available. The inside moisture as vapour is also trying to leave the house through cracks and gaps in the inside lining. Not only does this dry out the beds unnecessarily, but water vapour then condenses in the cooler insulation of the house. Many mushroom houses would have better insulation and less Winter drying-out problems, if only the inside shell was properly sealed—an easy operation to-day with modern materials.

Humidity is vitally important to mushroom growers at nearly all stages of cultivation. Although it is comparatively easy to control, I suppose it receives less attention than all other air variables. It is common practice to talk about relative humidity, meaning the ratio or proportion of moisture in the air to that in fully saturated moist air at the same temperature. For example air at 60° F. dry-bulb and 80% relative humidity contains four-fifths as much moisture (in the form of water vapour) as air at 60° F. and 100% R.H.

As a matter of interest the 1.0 p.m. June-Sept. dew-point temperatures average 50 to 55° F.—very close indeed to that required for a mushroom house. You often need humidification from October to May if excessive drying of the beds is to be avoided, but it is much less necessary during the Summer months.

Purity. Air is a mixture (by volume) of Nitrogen 77%, Oxygen 21%, Moisture as water vapour 1%, with small amounts of other gases 1%, including carbon dioxide 0.03%. Unfortunately the exact requirements of the growing mushroom are not yet fully understood. It is known that growing mycelium requires only a little oxygen, and it is entirely practical, in fact it is often desirable, to give no ventilation or fresh air during the spawn run. The reverse is the case when the mycelium is fully run through the casing and begins to " pin ".

It is my personal belief that the fresh air required is at a maximum at the same time as the mushroom growth rate is at a maximum—i.e. during the heavy 1st and 2nd flushes, from the well developed pin-head stage up to picking.

It is now believed that the growing mushroom produces a gas or gases of which minute amounts are self toxic, unless they can be freely diluted and removed by adequate fresh air ventilation.

It is most unlikely that lack of fresh air could in practical commercial growing lead to a dangerous carbon dioxide concentration or oxygen deficiency.

Movement of air is necessary in order that all parts of the house may have equable conditions of air purity, temperatures, etc. Its importance increases with the ratio of growing area to house volume. It is possible to grow mushrooms of the finest quality at optimum output with hardly any air movement—relying principally on diffusion to dilute and remove toxic gases. In practice this would mean upwards of 8 cubic feet free air space per square foot of bed area.

The modern trend is to increase the growing area in a given size of house to grow more mushrooms, without increasing building investment or heating costs. By using forced ventilation, properly applied through an air circulating system, I believe it is possible to reduce the free air space required per square foot of growing space to 4, or even less, until in fact practical problems of house management, including picking, become the limiting factors. Air conditioning has the further great advantage of providing more equable conditions the year round. The grower can more easily make adjustments and is not dependent on varying winds and temperature differences for fresh air supply and air movement.

Air Conditions for Growing Mushrooms

Now let us " leave school " and go to a mushroom farm. Before outlining some principles of ventilating or air-conditioning mushroom houses, I think we should attempt a survey of the air environment required at different stages of production. Please accept these assumptions as essentially personal opinions. Mushroom growers are well known for a healthy disagreement on the best conditions and methods of cultivation, but at least some of these suggestions can be adapted to individual preference.

Peak Heat-Conditioning. Let us begin with a horse-manure compost filled into a shelf house and ready for peak heating and final conditioning. The duration of peak heat-conditioning will depend on the condition of the compost. Personally, I favour the Lambert/Ayers technique of a short initial high peak heat of 140/145° air temperature with the compost 5/10° F. above the surrounding air. This is maintained for 6/8 hours and the air temperature then dropped to around 105° F. with the compost slowly falling to 115/120° F. From now on full sanitary routine is essential, including all possible precaution against the entry of flies. If forced fresh air is provided by a fan system, this should all come through a fine mesh gauze. These temperatures are maintained until the physical condition and smell of the compost *in all parts of the beds* is satisfactory.

What does this involve?—

(a) No fresh air is necessary immediately after filling, until the air temperature has reached about 100° F.

(b) Fresh air in continuous supply is necessary as soon as bacterial activity recommences, and the essential aerobic composting can proceed. It has been suggested that about 1 air change per hour is desirable. Personally, I insist that there be sufficent air, continuously supplied, to maintain full oxygen availability in the house. Opening the door once or twice daily is, in my opinion, inadequate, and can quickly lead to oxygen deficiency. It is only necessary to go into a "tight" house, which has been closed for 4/5 hours, to appreciate this point. Ideally, this fresh air should be heated and humidified as it enters the house. This will avoid cool dry areas, for not only is this fresh air 80°—100° less than house temperature, but it is relatively almost devoid of moisture.

(c) Even in well insulated houses there are substantial heat losses through walls etc., and the floor is slow to heat up. Because of this, and in order to equalise the bed temperatures as far as possible, it is essential to provide substantial air circulation in the house. In practice a difference of 3°-5° between " top and bottom " air, or between the beds is satisfactory and a fan or fans handling 15-25 recirculated air changes hourly should provide these conditions.

In special peak heat houses for tray growers, it is common practice to stack the trays almost solid, with only 1 or 2 inches between each tray. In such cases a properly designed air duct layout and tray stacking system, which will ensure air passing evenly through the tray tiers, is essential. It is asking for trouble if most of the air can by-pass the trays by travelling down gangways or across the ceiling.

(d) The method of heating will depend on available equipment. With live steam it is simple to heat and humidify the outside cold dry air as it enters the house.

Before we leave Peak Heat, I want to emphasise the importance of a fully oxygenated moving air supply always available to complete final conditioning of the compost. It is many year now since Dr. Lambert proved that mushrooms grew best in material *finally* composted aerobically at 115/140° F. Unfortunately, no ordinary compost heap leaves all the material in this ideal condition—there is often an anaerobic lower centre and a cool dry outer shell. The peak heat house is the logical place to bring all the compost to optimum conditions for growing mushrooms.

It is equally necessary to ensure that air conditions and the method of filling are such that aerobic composting is possible in all the beds, at all depths. The beds obtain oxygen for microbial activity from the surrounding air, partly by diffusion and partly by a slow upward circulation as in the compost heap. There is, however, only a small temperature difference of say 10° F. between the air in the beds and the surrounding air, to promote movement through the compost. It is difficult, therefore, to condition very deep beds satisfactorily. In two experiments I have cropped a ½ lb. more per sq. ft. by peak heating experimental deep trays in two layers put together on spawning. Obviously it is all a matter of balance and unsatisfactory final conditioning can be caused by :—

1. Insufficient fresh air reducing the normal oxygen supply.
2. Solid bottoms to beds—e.g. concrete, galvanised iron or bitumised paper.
3. Filling the beds very deeply.
4. Very wet short compost.
5. Heavy tamping on filling.

Spawn Run

On the completion of the peak heat/conditioning phase, the temperature can be dropped sharply prior to spawning. I know no valid argument for taking longer than necessary on this operation. Growing mycelium requires very little fresh air and most houses can

be closed completely with a moderate re-circulation in the house continued in order to maintain equable air-conditions and bed temperatures. Without some forced air re-circulation it is difficult, in cold weather, to prevent the top beds "going ahead" of those nearer the floor. The desirable air conditions after spawning are a temperature of 72/74° F. and near 100% R.H.

This will ensure the spawn running at its optimum in about 76° F. compost, with very little moisture loss. According to compost depth and the preference of the grower, the beds should be ready for casing in 10-14 days.

Growing

Picking should be possible about three weeks after casing, and the air environment during this interval is perhaps more important than at any other period of the cultivation cycle.

1. Little or no fresh air should be necessary during the initial mycelium invasion of the casing, provided the air temperature can be decreased about 1° F. daily.

2. Four to five days after casing it is desirable to admit some fresh air and start reducing the relative humidity in the house.

3. Ten to twelve days after casing, the temperature should be down to 60/62° F., perhaps with sufficient evaporation for light watering. First pins may be visible. Fresh air and re-circulation are increased.

4. " Bringing on the 1st Flush " calls for maximum ventilation by the time the beds are covered and reaching the small button stage. The danger of damage by toxic gases is never higher than at this period.

Air and the Casing

This is a suitable moment to discuss the effects of air environment on the casing layer—particularly during the period following casing. " Stroma " is an excessively vigorous growth of mycelium, brought about by faulty conditions in the casing layer. It is within the control of the grower, given suitable ventilation.

A fully-run compost, particularly if it is on the dry side and covered with a saturated peat/chalk casing, is potentially dangerous. Unless the house temperature is steadily reduced after casing, with moderate ventilation a few days later, all the ingredients exist for a first-class " Stroma." Watering the casing will certainly stop surface " Stroma " but will not cure " deep " Stroma. Fully run mycelium will vigorously invade the casing layer with eventual Stroma, if the casing condition is made too attractive. Principal attractions are temperature and, to a less extent, moisture.

Steadily reduce the temperature and humidity in the house and the casing will always be colder than the upper compost layer. Increased ventilation produces cooling by evaporation and the casing surface also dries out, becoming less attractive to the mycelium. Create this gradual decrease of temperature and moisture between the top layer of the compost and the casing surface and " Stroma " should not develop.

Air and the Mushroom

What are the temperatures, humidity, fresh air and air movement conditions ideal for mushrooms? This monumental question cannot be answered with certainty.

1. A temperature of about 60° F. is a good average for commercial growing.

2. Temperature variations of up to 5° F. do not usually upset cropping and, of course, have a considerable influence on the growth rate.

3. Reducing the growing temperature to say 55° F. not only immediately slows output but the rate of continuous growth at this temperature is always considerably slower. It probably reaches a near maximum around 62° F. and is, for example, little higher at say 70° F. Perhaps this should be explained more fully. Of course, the growth *cycle* is faster at 70° than at 62°, but the steady output of saleable mushrooms is little, if at all, higher. Apart from an increase in the ratio of stalk to cap weight, it would seem there is an optimum rate of conversion, or absorption, of food from the compost by the mycelium. Suddenly raising the temperature from 62° to 70° only very temporarily speeds production.

4. With suitable air movement and humidity it is possible to grow mushrooms at 75° to 80° F. but pests and disease make such temperatures undesirable.

5. The ideal relative humidity in a growing house is complex and depends on the state of the crop, the air temperature and its movement. In naturally ventilated houses, with nearly "still" air, a relative humidity of 80—85% should be satisfactory. In "crowded" forced ventilation houses, it may be necessary to maintain a rather high humidity of around 90%. In high temperature conditions the relative humidity should be reduced if possible. The greater the air movement, the higher the permissible humidity. Always, however, the mushrooms and the casing will tell the grower whether his humidity and air movement are satisfactory.

6. Fresh air requirements are unfortunately still a matter of personal opinion and no really exhaustive experiments seem to have been carried out. I believe the optimum varies with the state of the crop, and obviously, if we talk in terms of fresh air changes, it must vary greatly with the density of loading in the house (whether at 4, 5 or 6 cubic feet air space per sq. ft. bed area) and also with bed depth.

My personal recommendation would be for 2 to 4 fresh air changes per hour. This might only be necessary at optimum growth, during the heavy 1st and 2nd flushes. I believe that fresh air deficiency is a cumulative evil. No great harm necessarily occurs if all fresh air is cut off for several hours several times weekly (as might be desirable in very hot weather) but permanent damage by toxæmia may result from sustained fresh air deficiency early in the crop.

Probably many of the reports of abnormal mushrooms, such as leggy or lighthouse shapes, dying pinheads, woody and hard gill mushrooms, as well as those mysteries of moon and weather influences

are the result of insufficient fresh air or air movement creating a toxic condition in the compost/casing layer.

7. **Air movement** is another complex condition. Without doubt excellent mushrooms can be grown in " still " air, or in " moving " air only a little below the accepted draught level of 30/40 feet per minute. In the latter case, a high relative humidity is necessary, whereas in " still " air a lower humidity is permissible and a much higher air to bed ratio essential. In houses ventilated by natural means and provided with top and bottom vents it is probably best to provide at least 6 cu. ft of free air space per sq. foot of bed area during the warmer months of the year. In cold weather additional re-circulation of air in the house is produced by the heating system, and the fresh air supply increases because of " chimney draught " (heavy cold outside air tends to replace warm light air in the house).

In warm weather an extract fan will correct the overall fresh air supply but does not guarantee equality in all parts of the house.

In houses provided with forced air circulation the following broad principles apply:—

1. The fan and duct system must be such that all parts of the house are influenced without draught. This means that air movement immediately above the beds should not exceed 15/25 ft. per minute.

2. It must be possible to vary the amount of fresh air entering the house and it is suggested that 2—4 fresh air changes per hour is necessary (according to the type and density of the beds).

3. Humidity control (either manual or automatic) is highly desirable.

To ensure that air movement over the beds does not exceed 15/25 ft. per minute means that no primary air, i.e. air from fan or duct outlets, must pass immediately above any shelf or tray. Air movement above the casing should be entirely secondary, i.e., air disturbed or in movement as a result of induction by primary air streams. Primary air discharge is always a problem in mushroom houses and the final result usually a compromise.

The last part of this article outlines some methods and equipment which can be used by growers to obtain the conditions they require for mushroom cultivation.

The insulated growing house, steam piped with top and bottom vents for natural air circulation, is well known to you all. I want first to illustrate what happens in certain conditions:—

1. Winter — heat on

(a) Excellent natural internal circulation with warmed air carried up the sides of the house creating slow secondary movements over the beds.

(b) Temperature difference creates a good chimney affect, drawing in fresh air through the bottom vents. Unfortunately, in practice, this is difficult to control and the usual result is either waste of heat or, if the grower shuts down too far, possible fresh air deficiency.

(c) Cold fresh air in Winter often has a dew-point and moisture content very much below that required in the house. Unless some method of humidification exists the rate of evaporation, and therefore drying of the beds, can be excessive. Obviously on really cold nights, with air at or below freezing point, this problem is a serious one.

2. Summer — heat off

There is virtually no air movement in the house unless:—

(a) There is sufficient wind from the right direction to get air in, and out of the house vents (or through the doors).

(b) Extract fans, or mobile fans in the gangways, are provided.

The conditions are often so changeable that the grower on a commercial farm cannot possibly make the almost hourly adjustments needed to give constant conditions—he would be a superman indeed if he knew what continual adjustments to make for varying wind, temperature and humidity.

Does this mean then that his position in Summer is impossible in the usual growing house? Not at all. It does mean, however, that he must play safe. He must rely partly on diffusion for bed ventilation, and he must provide a generous air to bed ratio. Without forced fresh air, he dare not screen his ventilators against flies. What are the alternatives?

Air Conditioned Houses

Air conditioning is a general term, and can mean almost anything. For our purpose it should provide reasonable control of temperature, humidity, purity and movement of the air by the grower.

Air conditioning for human comfort has become almost a " MUST" in hot climates and is already widely used in this country industrially where a manufacturing process calls for specific air conditions.

Since the last war our own mushroom industry has slowly awakened to the advantages offered by suitable mechanical equipment for automatic heating control, and for forced ventilation—particularly by extract fans. In recent years a number of air-conditioned houses have been built on the Continent, and a few growers in this country have adapted existing houses and provided forced ventilation with recirculation and, in some cases, control of humidity.

Perhaps, fortunately for me, it is beyond the scope of this paper to describe in detail any complete air-conditioned system suitable for a mushroom house. May I, instead, take the individual conditions and outline some equipment possibilities.

Temperature

Heating methods are well known to you and I propose only to refer to the Summer problem of temperature reduction. It has already been stated that it is possible, in theory, to reduce the temperature of wetted

areas to the wet-bulb air temperature. In mushroom houses it is often practical to obtain some benefit by evaporative cooling from the beds and floor. The humidity inside the house must not be allowed to reach saturation however, and the grower must avoid over watering.

In sustained hot weather, with the outside wet-bulb temperature reaching 65° F. or more, the grower is faced with real problems. Over-production, invariably on a Monday or after a Bank Holiday with low prices. The prospect of damaging a new house by disease. Uncontrollable spawn run into the casing, leading to " Stroma ". All of these evils would be at least reduced, if only some cooling by refrigeration was possible and practical. To provide refrigeration for the whole plant would be quite prohibitively expensive—nearly £1,000 per house. Can nothing be done on an economic basis?

I suggest it can, and perhaps some wealthy large grower would care to approach the Manufacturers for a small *mobile* air cooling unit and do some experimenting.

In theory, the grower would use this unit like a General with an armoured division, bringing it into use wherever it could make the biggest effect. Calculations suggest that a 2 h.p. refrigerator with a 12 inch fan cooling unit removing 20,000 B.T.U. per hour would be a useful weapon in well insulated small houses. The cost should be about £600.

These are several obvious problems to overcome, including sanitation, but they should not be impossible.

Humidity is usually confined to the problem of increasing it during the cooler months of the year. Apart from the well known practices of spraying walls, floors and wetting the heaters, there are several simple ways of increasing the relative humidity in the house.

1. A small boiler, or tank, electrically heated will add water vapour to the air by steaming. A capacity of 3 to 5 pounds of water evaporation hourly (1 to 2 K.W.) should suit the average growing house in Winter. The unit could be automatically controlled by a humidistat or could include an immersion heater fitted with " Off ", " Half " and " Full " position switches at the control of the grower. In an air-conditioned house the humidifying element should feed into the main air supply. In steam heated houses it is possible to release a small quantity of live steam. Control is however difficult and a suitably placed fan is essential.

2. Another method of humidification uses a small atomising spray, connected to mains water, with surplus running to waste. This technique can only be used where it is possible to spray a heater panel, or hot pipes, or where a fan and duct system is in use. The equipment and control is more complicated than the electric boiler, but has the advantage of not adding heat to the air.

Purity

This has already been discussed. Sufficient to say that in air-conditioned houses the air purity should be more easily controlled and therefore constant, than in naturally ventilated houses. Fresh air will be admitted through one opening only, which can be protected from winds and screened from flies.

Movement of Air

Unfortunately a fair presentation of the modern equipment, methods and design rules for carrying into practice the grower's requirements, is beyond the scope of this article.

DISCUSSION:

With what is known as the Plenum System, you get fairly high velocity air streams from the outlets in the canvas ducting, and you must be careful that these air streams are a long way away from the surface of the beds because the velocities anywhere near the outlets are far beyond what would be reasonable over the actual growing area.

I know of no instrument that will accurately give you a fair estimate of the movement of air over the casing soil. It is so slow that I suggest you could test it with cigarette smoke; but it is very inaccurate.

I have just received news of the latest product to be **quick-frozen: Mushrooms.** The first consumer pack sells at 1s. 8d. Catering packs are to be marketed later, to hotels and restaurants. The contents of this colour-printed carton are cultivated and quick-frozen by Linfields Ltd. at Thakeham in Sussex. I understand that, since mushrooms shrink in size when cooked, these Chesswood products are partly cooked. The quick-freezing is carried out in a multi-plate Jackstone froster. The consumer packs go out in twelves in an outer case.

A. E. Hammond in *Fruit Trades' Journal*, March 8/58.

CASING LAYER ADDITIVES

P. B. FLEGG

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Since 1955 one of the problems under investigation at the Glasshouse Crops Research Institute at Littlehampton has been the function of the casing layer. The main objective is to discover the processes leading up to the formation and development of sporophores and to study the factors which affect them. It is one of the fundamental problems being tackled at Littlehampton and involves investigations and experiments which may seem to have no direct bearing on the immediate problems of the mushroom grower. However, such fundamental research will be of considerable benefit to the grower in the long run and it is quite likely that results of practical value will emerge as the work proceeds, often without intent on the part of the research worker. This paper is concerned with results which have arisen in that way and which may be of interest to growers.

Addition of Salts to the Casing Layer

For many years growers and scientists have been interested in the possibility of beneficial effects from adding some substance or substances to the casing layer either at casing or during cropping. Possibly some sort of analogy with the practice of top dressing agricultural crops has been in their minds. Surprisingly, there is very little direct experimental evidence to indicate whether the idea is sound or not. Both Dr. B. B. Stoller (1952) and Dr. R. L. Edwards (1953) have carried out some experiments, but no conclusive results were obtained.

Several growers add common salt (sodium chloride) to the casing layer as a standard practice, claiming that the quality of their mushrooms is improved and that some freedom from disease is obtained. Some small scale experiments have been carried out at Littlehampton in order to investigate the effects of the addition of a variety of salts to casing soil both from the nutritional and physical aspect. The details of these experiments are to be given in the G.C.R.I. Annual Reports.

During the course of these experiments, salts containing N, P and K, such as ammonium and potassium sulphates and sodium phosphate, were used to investigate possible nutritional effects and the results compared with those obtained when sodium sulphate, presumably having no nutritional value, was used. The addition of these salts to the soil soon after casing at a rate of about 50-300 lb. per 1,000 sq. ft. had a very marked effect on fruiting, usually irrespective of the kind of salt used. The number of fruiting bodies formed was considerably reduced with increasing levels of application, but the mean weight of those which did develop was considerably increased; that is, fewer but heavier mushrooms were produced. This effect has been consistent throughout several experiments. At the levels of application which were used in these experiments there was in most cases a reduction in the total weight per square foot. However the dosages were rather high, much higher than is likely to be used by any grower.

It seems, therefore, that the claims of improved quality—that is, heavier and bigger mushrooms—due to the application of salt to the casing layer, now have a measure of experimental support. Those troubled with crops of very small mushrooms of poor quality and requiring considerable labour for picking may find that the application of salts to the casing layer is beneficial. The results obtained at Littlehampton so far do not allow any recommendations to be made either on which salts to use or the optimum time or rate of application. Perhaps growers who already carry out the practice may have some of the answers. Work on these aspects of the casing problem is continuing and we have already obtained evidence that under normal growing conditions salts tend to accumulate in the casing layer, presumably coming from the compost below. It remains to be seen to what extent this is important; the salt content of the compost may be of some significance. In order to help in these investigations several growers have kindly supplied samples of their compost for analysis.

The main conclusions so far are that the addition of some salts to the casing layer can reduce the numbers of mushrooms, and those which do form and develop are generally heavier and larger. At high levels of salt addition the total weight of the crop is reduced. If the reduction in numbers can be attained without appreciable loss in yield then picking labour is reduced and some improvement in quality is obtained.

Addition of Sources of Nutrient to the Casing Layer

The view that mushroom mycelium is encouraged to form fruiting bodies when it passes from a medium of high nutrient status (in the compost) to one of low nutrient status (in the soil) has been put forward many times. Consequently a casing medium which may be rich in nutrients has never been of much interest to growers. With the intention of investigating this aspect experiments were carried out at Yaxley (Flegg, 1954), in which compost was mixed with the casing soil in various proportions. Mixtures of soil : compost of about 2 to 3 : 1 gave increases in yield. It was thought that this may have been due to an improvement of the physical nature of the casing soil, particularly an improvement of pore space. Unfortunately the closure of Yaxley did not allow further experiments, but it has been found possible to continue them since moving to Littlehampton.

The first experiment on this aspect at the new research station was a pot experiment in which compost was taken from the stack at filling, dried in the open air, milled to pass a 2 mm. sieve and added to the casing soil at 50, 100 and 200 g. per pot; 50 g. per pot is equivalent to about 5 oz. per square foot. In all experiments the compost used was MRA synthetic. The cropping details are shown in Table I. The addition of milled dried compost at the higher levels delayed fruiting, but yields were not adversely affected. There was an increase of about 50% in yield due to the addition of 50 g. of compost to the casing layer while heavier additions, even up to 200 g. per pot, gave higher yields than the pots to which nothing was added.

A bed experiment was then set up in which additions of 0, 2 and 4 oz. of milled dried compost per square foot were added to the casing soil immediately after casing. Table II shows the results of this experiment after 8 and 10 weeks cropping. A significant increase in yield of between 20-25% was obtained at both the 2 oz. and 4 oz. levels, confirming the beneficial effects of adding compost to the casing soil found in the pot experiment. As in the pot experiment, the addition of dry compost to the soil delayed the onset of cropping by a few days.

The increased yields may have been due to improvement of the physical state of the soil by the addition of compost, or to the extra source of nutrients supplied by the compost. It was noticeable that the compost mixed with the casing soil was readily colonised by the mushroom mycelium. Tables I and II show that the increases in yield are accompanied by an increase in the mean weight of each mushroom rather than the production of more mushrooms; this is indicative of a nutritional effect.

Table I.

	Wt. of compost added to soil (g. per pot)			
	0	50	100	200
Days, casing—1st pinheads	18·8	21·2	24·4xx	27·2xx
Yields at 10 weeks. g. per pot ..	124·6	194·0xx	143·4	163·4x
Nos. per pot ..	14·6	21·0xx	13·8	12·4
Mean weight per mushroom (g.) ..	8·6	9·2	10·4	13·1

x Significance at 5% probability.
xx Significance at 1% probability.
A yield of 150 g. per pot is equivalent to 1 lb. sq. ft. approx.

Table II.

	Weight of milled compost added per sq. ft. of casing soil		
	NIL	2-oz.	4-oz.
Days casing—1st pinheads	17·5	18·25	20·25xx
Yields at 8 weeks. lb. sq. ft. ..	1·14	1·44xx	1·42xx
Nos. sq. ft. ..	50·9	50·2	43·7
Yields at 10 weeks. lb. sq. ft. ..	1·32	1·59x	1·58x
Nos. sq. ft. ..	58·1	55·0	50·5
Mean weight of mushrooms at 10 weeks (oz.)	0·36	0·46	0·50

x Significance at 5% probability.
xx Significance at 1% probability.

In order to examine the causes of the increased yields another bed experiment was planned in which two levels of milled compost, 3 and 6 oz. per square foot, were added to the casing soil and to a peat and chalk mixture. Milled peat was also added to soil at the rate of 3 and 6 oz. per square foot in order to compare the effect of this with the addition of the same levels of milled compost to soil. In this experiment the dried milled compost was rewetted before application to the casing layer. It was thought that if the effect was physical then the addition of milled peat to the soil would have the same effect as milled compost. As peat and chalk is now more popular for casing in Great Britain, it was considered of interest to discover whether yields with this type of casing could also be increased by the addition of compost.

This experiment, the results of which are shown in Table III, proved disappointing as none of the differences between the treatment yields could be shown to be statistically significant owing to excessive variation between beds of each treatment.

Table III.

	Soil + Nil	Soil + 3 oz. compost per sq. ft.	Soil + 6 oz. compost per sq. ft.	Peat and Chalk + Nil	Peat and Chalk + 3 oz. compost per sq. ft.	Peat and Chalk + 6 oz. compost per sq. ft.	Soil + Nil	Soil + 3 oz. peat per sq. ft.	Soil + 6 oz. peat per sq. ft.
Days, casing — 1st pinheads	28·3	26·8	25·0	27·5	26·8	28·5	28·3	26·8	29·0
lb. sq. ft. at 8 weeks ..	1·55	1·62	1·69	1·57	1·59	1·74	1·55	1·54	1·60
Nos. sq. ft. at 8 weeks ..	39·2	38·2	34·7	42·2	43·8	38·3	39·2	48·3x	45·1
Mean wght. per mushroom (oz.)	0·63	0·68	0·78	0·56	0·58	0·74	0·63	0·48	0·57

x Significantly different from soil alone.

Although none of the differences between treatment yields was statistically significant, a general tendency for increased yields to be produced from beds treated with compost is evident. From the numbers of mushrooms produced the effect of the addition of milled peat to soil can be seen to be quite different from that of milled compost. Milled peat significantly ($P < 1\%$) increased the numbers whereas milled compost did not. There was a tendency for fewer mushrooms to be produced on beds cased with soil plus compost and as in earlier experiments the mushrooms were heavier.

These results cannot be regarded as conclusive but suggest that the effect of milled peat is almost entirely physical, possibly connected with an increase in the soil pore space of the casing soil. Although milled compost may also have some effect on the physical properties of the soil, it tends to produce heavier crops because the weight of each mushroom is greater, rather than from an increase in the number of mushrooms. This is suggestive of a nutritional effect. Increased yields of heavier mushrooms probably arise from the extra source of nutrients supplied by the milled compost in the casing layer. In the

previous bed experiment the addition of 2 oz. of dried compost per square foot gave rise to an increase in yield of 0·3 lb. per square foot at 8 weeks (0·27 lb. at 10 weeks), that is, over $\frac{1}{4}$ lb. per square foot. The production of over 4 oz. fresh mushrooms from 2 oz. dry compost represents a rate of conversion many times greater than is achieved by the compost in the bed below the casing layer. The rate of conversion in the bed is probably of the order of 4 oz. fresh mushrooms from 8 oz. dry compost. Thus there is the possibility of increasing the productivity of compost by incorporating it with the casing layer.

Rewetting of the milled compost before application to the casing is shown in Table III to have avoided the delay in fruiting found in previous experiments. It was also found that the rewetted compost was much easier to apply than when dry.

Practical Aspects

To summarize the results in terms of their possible value to mushroom growers, the main points are:

I The application of dilute salt solutions to the casing layer, already practised by some growers in order to improve mushroom quality in terms of weight and size now has a measure of experimental support. Labour requirements for picking may be thereby reduced. There may, however, be drawbacks to this practice as excessive quantities of salt will reduce yields considerably. At the moment the experimental results do not allow any recommendations on the kind of salt or optimum time and rate of application to be given.

II (a) There is a distinct possibility that yields may be increased by the addition of compost to the casing layer and that this compost may be more efficiently converted into mushrooms than the compost below the casing layer.

(b) Compost added to the casing layer also tends to increase the mean weight of the individual mushrooms produced, thus improving quality and reducing picking labour. This may be connected with the presence of salts in the compost (See I).

(c) The use of milled compost may be difficult for growers and it is necessary to discover whether compost, as taken from the stack, can be used with equal advantage. It is also of importance to determine the best quantity of compost and whether it should be previously peak heated.

The mixing of compost with the casing layer may cause, initially, some cultural difficulties. When the mycelium has completely colonised the compost in the casing there are areas of the casing surface which are then impossible to water and look most untidy. This need cause no alarm and these areas should not be soaked in an attempt to wet them. The use of compost in casing mixtures, especially if not peak heated, may also promote pests and diseases though no trouble from this cause has been experienced at Littlehampton.

For practical purposes it may be noted that 4 oz. dried compost is equivalent to about 1 lb. wet compost.

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DISCUSSION:

By adding salts to the casing we may make it less attractive to the fruiting mycelium. Fewer mushrooms result, and they can call on a relatively heavier concentration of food material, so they grow larger.

I doubt whether the addition of *spent* compost would be beneficial.

I imagine that, commercially, it would be desirable to add the pulverised compost to the casing material before it is put on the beds.

Mushrooms frozen by the Flavor-Lok Corporation of Wilmington, Del., have an advantage over fresh mushrooms in that they reach the consumer in virtually the same state as when they are picked. They reconstitute extremely well, retain the flavour and texture of fresh mushrooms and are juicier. They don't turn into mush when cooked.

AMI's *Mushroom News*, February/58

New developments may include such things as mushroom seasoning salt, pre-sliced fresh mushrooms ready-for-the-pan, and a liquid steak sauce from mushroom juice.

Robert Bull in AMI's *Mushroom News*, February/58.

THE INVESTIGATION OF SOME MUSHROOM DISORDERS

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In March 1948, a serious disorder of mushrooms occurred on the farm of La France Brothers, Chester County, Pennsylvania. This was fully described by Sinden (5) who named it La France Disease. Some years later it was reported in this country for the first time, the diagnosis having been confirmed by Sinden himself. Many similar outbreaks followed, but it soon became apparent that not all of them conformed with the published description of La France Disease. The identification of this disease, by means of the description published by Sinden, is difficult as the symptoms appear to be somewhat vague and variable. An investigation of these disorders was begun in an attempt to clarify the situation. It has had a somewhat chequered career, having been restricted by lack of facilities at various times and consequently a systematic attack on the problem has not been possible. This paper attempts to bring together the observations and experimental results obtained so far.

Mushroom diseases generally occur in cycles and La France does not seem to be so frequent now. " Brown Disease " and " Watery Stipe " are names which have been given to two more recently noted disorders. All of them appear to fall into the same general category and since it is impossible to tell how many different disorders do in fact exist, each outbreak has had to be studied individually.

The study of a disease falls broadly into three sections, namely identification, cause and cure. Identification from symptoms is of great importance to growers. What are the symptoms which they have seen in these outbreaks? Our recent questionnaire showed that 46% of those replying had seen some of the symptoms mentioned in the La France section. Of these 67% said that the mushrooms died before reaching maturity, 72% had mushrooms showing deformities of various kinds, 67% said that the disorder spread during cropping and 44% claimed that cropping ceased prematurely. The symptoms were most frequently observed in the third flush. This information has been given by growers, and obviously individual judgment varies. More consistent data are obtained if one person can look at different outbreaks and compare them. This has been done where practicable, but it has only been possible to deal with a small number of outbreaks in this way. Descriptions of four such outbreaks have been given elsewhere (1). The symptoms seen on inspections of this kind (S. and S.E. England) have fallen into the following categories:

1. **Death of Mushrooms Before Reaching Maturity.**
   The mushrooms assume a putty-like colour and consistency, becoming discoloured when handled. Under dry conditions they shrivel and become mummified. Where conditions are more humid the mushrooms may become slimy, brown and decay as a result of bacterial action.

2. **Waterlogged Tissues, especially in the Stipe.**
In extreme cases the whole stipe becomes waterlogged and transluscent, but more commonly longitudinal streaks, often surrounding a cavity, are found in the stipe tissue. This corresponds with the " watery stipe " disease described by Lester (4).

3. **Mushrooms without Gills or Veils.**
The tissue in these cases is often hard and gritty. This is not a new condition, as it was fully described by Hein in 1930 (2). It is interesting to note that on one farm where this deformity appeared, accurate plotting of the position of mushrooms in succeeding flushes showed that this type of mushroom reappeared at the same places on the beds. Spawn made from tissue cultures of such mushrooms produced normal sporophores.

4. **Sporophore Deformities.**
Considerable variation is shown, from a slight elongation of the stipe to extreme cases where the mushroom resembled a drum stick. In other instances the stipes are swollen to such an extent that their diameters are almost as great as those of the pilei. (See illustration from *MGA Bull.* 84 p. 398, reproduced below.)

5. **Poor Development of Mycelial Strands.**
An abnormally small number of mycelial strands connecting the mushroom with the mycelium is commonly found. This is generally accompanied by a fluffy growth of mycelium at the base of the stipe. Insects pests cannot be found which would account for this condition. The absence of an adequate translocating system may account for the early deaths of mushrooms.

Reproduced from the Littlehampton collection with the permission of the Controller of H.M. Stationery Office.

6. **Decreased Cropping.**

Often a quarter or less than normal, with the absence of any obvious pest or disease which could account for this condition. The type of grower and general standard of management has to be taken into consideration when assessing these crop losses.

Taken singly, most of these symptoms would not appear to be very significant, but when occurring in combination it becomes evident that some disorder or disorders, admittedly of a somewhat nebulous character, is present.

The question of the cause or causes of such disorders comes next. The outbreaks investigated have shown that in most cases no known pest, disease or cultural practice could account for the trouble. Examination of the compost showed that the spawn had run well and was still in good condition and apparently capable of cropping in a satisfactory manner. In an early experiment beakers of pure spawn were inoculated with compost or casing from infected beds or with a water extract of dead mushrooms. The beakers were cased with steam sterilized soil. Death of mushrooms occurred with all three types of inoculum (taken from several farms), whilst in other cases fruiting was completely suppressed. Normal mushrooms were produced on the control beakers. On the other hand, in another similar experiment (described more fully in a later section), water extract of compost, casing and mushrooms, when sprayed on to a bed in full production, had no effect. These experiments were carried out on a very small scale and the results cannot be regarded as conclusive.

At the Brighton Conference, Sinden mentioned that mushroom mycelium (in good condition) taken from a crop suffering from La France Disease would not grow on agar media in pure culture. This test was applied to all the cases subsequently investigated. When the mycelium was in good condition, no difficulty was found in establishing pure cultures, but it soon became apparent that some of them did not have the normal habit of growth. In pure culture mushroom mycelium is usually white and fluffy, forming strands which radiate from the centre of the colony. The abnormal cultures had thin straggly mycelium, often buff coloured, and no strands. This type of growth has been described by other workers studying the morphology of cultures of the mushroom (3, 6, 7). The rates of growth of these different types of culture are shown in Table I.

Not all cultures have behaved in this way, but it seems to be a useful method of sorting out some of these disorders.

Further information about the behaviour of these abnormal mushroom strains was obtained by making spawn from them and using it in cropping experiments carried out in a mushroom house. The first two experiments were not very successful for a number of reasons. The mushrooms were grown in 10 inch concrete pots which required daily

Table I

Mean Diameters of Colonies three weeks after inoculation.

Original diameter 7 mm.

Mycelium from five different commercial spawns					Mycelium from abnormal crops						
1	2	3	4	5	D/1	D/2	T/1	S/1	M/1	G/1	L/1
57	58	41	62	58	43	21	43	22	36	25	50

watering and it was found that the less vigorous spawns did not survive under these conditions. The results obtained, however, indicated that these spawns produced poor crops, so a further experiment was carried out, using beds each approximately 9 sq. ft. in area. MRA synthetic compost was used, the beds being peak heated and spawned in the usual manner. Steam sterilized local soil was used for casing, but this soil is not very suitable as it pans badly after watering and tends to retard cropping if not broken up occasionally. Peat casings had to be avoided as some growers have associated these disorders with their use. The following spawns were used:

D/1/2—originally from Kent.
D/2 — „ „ „ (same farm)
T/1 — „ „ W. Sussex.
S/1 — „ „ „
H/1 — „ „ Surrey.
L/1 — „ „ Worcs.
Control—A Strain derived from a commercial spawn which had given a satisfactory crop.

The yields from these spawns during the first six weeks' cropping are shown in Table II.

Table II.

Mean yield per bed after six weeks' cropping.

Spawn	No. of mushrooms	Weight grms.	oz./sq. ft.
D/1/2	77	1919	7·4
D/2	84	2234	8·6
T/1	61	947	3·6
S/1	71	969	3·7
H/1	19	272	1·0
L/1	89	1915	7·4
Control	158	3840	14·9

In the first two experiments (with pots) the only abnormality observed was a slight lengthening of the stipe. In the bed experiment, some mushrooms produced by spawns D/2, S/1 and T/1 died in the late button stage, but cropping was so sporadic and poor that it was not possible to determine whether the condition was spreading or not. One bed of D/2 produced a flush of mushrooms all of which died, but the next flush which appeared a month later was quite healthy. Some mushrooms without gills or veils also occurred. These experiments indicate that there may be wide variations in the cropping potential of these spawns, and other strains await trial.

Microscopic examination has failed to reveal any differences in the morphology of these different cultures. The slow growing types are less branched and have smaller deposits of calcium oxalate crystals.

The effect of environmental conditions on the incidence of these disorders, and the symptoms produced, cannot be investigated at present. A little information has however been obtained, by transferring sections of beds or whole trays from farms to the experimental house or some other available building. This has illustrated that disorders with similar symptoms do not behave in the same way. On one such tray the mushrooms in one corner were brown, dying and slimy when removed from the farm. When the next flush appeared all the mushrooms, except those farthest from the original infection, were similarly affected. The third and subsequent flushes were perfectly healthy. Sections of bed from two widely separated farms were placed in trays and kept in the mushroom house. They continued to crop, but the mushrooms were small, with bent stipes, and died while still immature. These were the same symptoms as had been seen on each farm. At present lack of space prevents more extensive trials of this nature.

Water extracts of mushrooms, compost and casing from the two bed sections mentioned above were made and each divided into two. One half of each was sprayed on to the mushroom beds in crop, the remainder being passed through a bacterial filter before being applied to the beds. There was no apparent effect on the mushrooms.

These water extracts were also used in a laboratory experiment, with more interesting results. The following treatments were given:

1. The water extract was added to a malt agar medium and then sterilized.
2. As (1) but the medium not sterilized.
3. The water extract was passed through a filter to remove bacteria and fungus spores before being added to sterile malt agar. These media were poured into Petri dishes and inoculated with a vigorously growing mushroom culture.

Growth of mushroom mycelium with sterilized and filtered extracts was good and similar to that in control dishes which contained malt agar only. There was extensive bacterial growth with the unsterilized, unfiltered extract which resulted in almost complete inhibition of mushroom growth. This occurred with both extracts and indicates that in these cases mushroom growth was affected by the presence of bacteria rather than the presence of filterable virus or toxins (other than those produced by growing bacteria).

Summary of Possible Causes.

The study of mushroom disorders of the type described is obviously a long and complicated one. No definite conclusions as to the causes of such disorders can be drawn at this stage, but it is perhaps useful to review and comment upon some possible causes.

1. A virus. No virus is known to attack fungi, in fact all known viruses are confined to flowering plants. If there is an organism akin to a virus attacking mushrooms then a whole new field of investigation would open up. Attempts to turn a normal type of mycelium into a slow growing type by means of inoculations of various kinds have failed.
2. Bacteria. Mushroom mycelium is sensitive to many bacteria, and bacterial contamination of mushroom cultures can completely inhibit growth. These bacteria have not been closely studied or identified, and it is not known in what concentrations such bacteria occur in compost nor what concentrations would be necessary to inhibit mushroom growth under these conditions. As to the bacteria found on dying mushrooms, they may be purely saprophytic types and unconnected with the disorder.
3. Genetical causes. The variations in the appearances of different mushroom strains observed in this investigation are consistent with genetical differences. Kligman, Sinden and Stoller (5, 6, 7) have described such variations in papers dealing with the cytology and genetics of the mushroom. Single spore cultures which have been made have produced a number of cultures similar in appearance to those obtained from abnormal crops. A small scale experiment indicated that these cultures were also poor croppers. Mushroom cultures appear to be fairly stable, so it seems unlikely that the differences observed in the cultures derived from abnormal crops are the result of mutations unless there are predisposing factors of which we know nothing. Under laboratory conditions only one mutation has been observed in this investigation. A slow growing type D/2 produced a white, fluffy quick growing sector. This has not yet been cropped.
4. Physiological causes. The effect of transferring trays from one environment to another has shown that some of the symptoms observed could be the result of unfavourable growing conditions. Critical experiments have not yet been carried out.

The possible interaction between several of the factors discussed must also be considered. Obviously environmental conditions are most important as they may seriously modify the symptoms produced by a disorder.

The cure for these disorders must at this stage be a matter of guesswork. The behaviour of these disorders is in many cases consistent with the presence of an infective agent, and it is wise to assume that this is so in all cases. Where serious outbreaks have occurred they

have been overcome by thorough disinfection of the farm, with, if possible, a complete cessation of mushroom growing in order to break the cycle of re-infection.

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It's not easy to advise growers to **cut next year's volume** or to delay that extra double for a while. But they must do it for the sake of their own pocketbooks and for the sake of the industry as a whole.

Editorial in AMI's *Mushroom News*, February/58.

A NEW APPROACH TO PACKING

K. G. HARTLEY
Tavak Products

It is not the purpose of this talk to expound any scientific theories on the art of mushroom raising. This I feel can be safely entrusted to our friends who are speaking on the subject and to Mother Nature who I am given to understand does manage to raise a few without much trouble. It has even been alleged by a few of the baser types of individual that there is more flavour in mushrooms thus grown than in the cultured variety. However I have no doubt that it is merely a matter of time before even the most misguided person will turn from these false doctrines to appreciate the delicate flavour of true culture, particularly if they can be presented to the Consumer in a condition a little nearer to the " as picked."

There can be no doubt that the cultured product does suffer in many cases from the effects of time during the marketing process with the result that it often reaches the consumer more in the category of " an ancient monument " than fresh picked produce.

Several factors emerge as the result of the time lag between picking and purchase by the consumer:—

1. Loss of weight

This of course has an important bearing on price and as it is a variable factor according to the time lag it is particularly disturbing as no definite assessment can be made.

2. Growth during Transit

In the generally exposed conditions there does appear to be a continuation of growth after picking. It is understood that ' Buttons ' command a higher price than ' Flats ' and it would appear to be fairly safe to assume that a considerable loss of revenue is due to the fact that buttons as picked would, in the majority of cases, reach the consumer as flats:

3. Discolouration

Discolouration of the original white mushroom as grown is very rapid and generally provides an indication of age. Although the reduction of their original whiteness would appear to be a point on which the mushroom growers themselves are extremely fussy, from what one can gather generally from the public this does not seem to be quite as important in most cases as would be imagined. I have, in fact, heard it said by a member of the public in general conversation that the slightly discoloured mushroom has a better flavour than the white! This of course we assume is merely due to the fact that it more nearly approximates the colour of the field mushroom which after all is considered by most of the population to be the best mushroom. There can be no doubt, however, that the reduction of the original whiteness is important and it is in fact considered a major problem.

4. Deterioration of Gill Colour

The deterioration of the original pink of the gills is also extremely rapid and it is felt that this colour should be retained as long as possible.

With the object of eliminating these factors as far as possible we were asked by our good friend Mr. Guy Reed to conduct a few experiments in the packing of mushrooms in polythene in various ways. This we agreed to do and it is hoped that the results may prove of value to the growers generally.

Experiment 1

A quantity of mushrooms were left unpacked in a fairly dry atmosphere at a temperature of 62° F.; the mushrooms were in the form of buttons and the following results were recorded:

	Weight	Growth	Colour
1st day	2·7 oz.	Buttons	Good
3rd day	1·8 oz.	Slight Growth	Gills black Discolouration considerable
4th day	1·3 oz.	Considerable	Considerable
5th day	1·1 oz.	Very poor	Very poor
7th day	·4 oz.	Other factors ex	tremely poor

Experiment 2

Vacuum Pack—Although it was known that polythene in itself will not hold a vacuum for any length of time it was decided to try an initial vacuum with the following results:—

	Weight	Growth	Colour
1st day	3·5 oz.	Buttons	As picked, gills unexposed
3rd day	3·5 oz.	Nil	Slight discolouration
5th day	3·5 oz.	Nil	Slight discolouration

It was noticed on the 3rd day that there was moisture present in the bag and on opening after seven days the mushrooms were in fact quite wet; this of course dried out after being exposed to the air for a short period. To some extent the taste of these mushrooms was also affected in as much as there appeared to be a very slight fermentation giving a slightly stronger flavour to the mushroom itself. After seven days these mushrooms were distributed to members of our staff who pronounced them very good indeed.

Experiment 3

Blown Packed—Mushrooms were packed in a polythene bag, a quantity of air was blown into the bag and the bag was then sealed. This method produced a 'cushion' pack which would enable the contents of the bag to be protected against crushing. The results of this experiment showed that the weight remained constant throughout with slight growth and slight discolouration occurring after three days.

Experiment 4

Oxygen Packed. Mushrooms were packed as in the previous experiment but the bag was filled with oxygen. The weight remained constant throughout the experiment. Growth was considerable and the gills deteriorated within two days, but only slight general discolouration.

Experiment 5

Perforated bag. The mushrooms were packed in a perforated polythene bag. The weight remained constant, growth was slight throughout the experiment. The colour remained good for three days but deteriorated thereafter.

Experiment 6

Bunch Sealed. The mushrooms were packed in a polythene bag and the top bunch sealed. The weight remained constant, growth was very slight, and the colour was good for three days but deteriorated thereafter.

The general inference drawn from these experiments is that the packing of mushrooms in polythene in almost any form of bag does in fact practically eliminate weight loss, the 'as picked' condition is prolonged and is usually quite good up to four days, even saleable up to seven days. There does not seem to be any method by which the gill colour can be preserved but in view of the slight growth, it can be definitely retarded.

The air blown, oxygen or nitrogen filled bags do not appear to have any worthwhile improvements in consideration of the expense involved in packing. We also feel that this would probably apply to the straight forward vacuum packing.

A considerable improvement in general condition was also noticed when the complete chip was enclosed by a polythene bag and even when the chip was merely covered with a piece of polythene.

A further experiment was tried with the packing of mushrooms into a polythene bag, fitted with a draw string and sold direct to the public by Mr. Reed, with the idea of promoting the sale of mushrooms in a presentation pack. Although slightly dearer this met with a measure of success and the most popular colour for the bag was blue.

We feel that from the constant weight point alone the experiments may have proved useful, and in any event we did enjoy the leftover mushrooms.

PRELIMINARY OBSERVATIONS ON THE CECID PROBLEM

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The damage attributable to Cecids has come into increasing prominence in recent years and of the 82 replies to the Institute's Mushroom Questionnaire, 38 growers (46%) reported Cecid trouble in 1956 and of these 17 (21%) were sufficiently severe to reduce cropping.

A serious attempt to investigate the Cecid problem was initiated in January, 1957, and in this paper it is proposed to review current progress and the present state of knowledge. At the outset it must be stressed that our aim is to unravel the biological complexities as a preliminary to experiments on control.

The problem is a most unusual one, for mushroom Cecids have a mode of reproduction, known as "paedogenesis," which is almost completely unknown elsewhere in the insect world. Whereas in most insects a larva is destined to pupate and produce a single adult, the larvae of Cecids are able to produce further young larvae within themselves and so continue reproduction indefinitely, with only the occasional appearance of adults. This peculiarity has an important bearing on aspects of Cecid control in mushroom beds, for phenomenal numbers may be built up within the compost, giving no opportunity for control by external application of chemicals.

Species Complex.

Wherever a number of species is associated with pest damage it is essential to distinguish them in order that observations can consistently be made on the one under investigation. The importance of this will be demonstrated later in reference to the strikingly different maximum lethal temperatures of two very similar species.

Barnes (1946) lists six species of Cecidomyidae known from mushrooms. The American form *Mycophila fungicola* Felt has not been recorded in this country and we cannot, as yet, say in what characters it differs from our own *Mycophila* spp. Of the remaining five British species we have eliminated two. Speyer (1927) had recorded *Pezomyia vanderwulpi* (Meijere) from mushrooms at Cheshunt, but on re-examining his material we have identified it as *M. barnesi* Edwards which had not been described at that time. The record of *Miastor* sp. by Theobald and Barnes (1928) was based on larval material collected at West Barnham, Sussex. These larvae were placed in the genus *Miastor* as, at that time, it was the only genus known to be paedogenetic, but from Barnes' figure of the larvae it seems highly probable that they were *Heteropeza*, first recognised from material reared by Moreton in 1949.

Lestremia cinerea Macquart is a common Cecid, but the only reared material was provided by Speyer in 1937 from mushrooms growing out of doors at Eastbourne, whilst F. C. Wood caught the species in a mushroom house at Worthing. We have also taken a female in our own light-trap in the Institute's mushroom house, as well as large numbers in windows of buildings nearby. At present it seems that *L. cinerea* only occasionally attacks mushrooms.

The genus *Mycophila* contains two important pest species: *M. speyeri* Barnes and *M. barnesi* Edwards, both of which have been recorded from mushrooms. The former has been recorded at Congresbury (Somerset), Cheshunt, Abington, Rustington (Sussex) and Copenhagen (Denmark), whilst *M. barnesi*, which was described from specimens taken in windows at Letchworth, is also known from Cheshunt, Oxford, garden manure at Manchester, mushroom manure at East Grinstead, mushrooms at Yaxley, St. Germans (Cornwall), Biddulph (Staffs.), Doddington (Kent), rotting potatoes at Leeds, and peat intended for casing at Folkestone. To complete the list of *Mycophila* habitats, mention should be made of the discovery of *M. fungicola* in leaf mould, under bark, rotting straw and at the stem bases and roots of sweet corn in America.

By far the commonest species appears to be that identified as *Heteropeza* by Barnes, and this pest is now known from mushroom compost at Yaxley, Biddulph, Selby (Yorks.), Bridge of Allan (Stirlingshire), Washington and Rustington (Sussex). We have also found it in both unspawned and spent compost here, but a most interesting record is from a humic soil at Southampton. Ulrich (1936) records it from below birch bark in Upper Bavaria. Adult material from several sources has been compared with specimens in the Barnes collection at Rothamsted and no reliable differences can be found between the mushroom forms and *H. pygmaea* Winnertz (*Oligarces paradoxus* Meinert). Barnes' original material of this species was obtained from Birmingham in 1937 in a most unusual manner: the larvae appearing from the wooden body-work of an old Wolseley car each time it was washed down!.

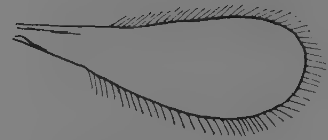
The separation of these three adult species of mushroom Cecids is difficult, being based on rather minute characters, but in the absence of any readily available information the following short key is appended:

1. Wings without veins (Fig. 1a), 2 tarsal joints *Heteropeza pygmaea*

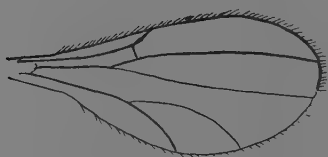
   Wings with veins (Fig. 1b), 4 tarsal joints *Mycophila spp. 2*

2. Tarsi bearing scales, empodium between tarsal claws short but distinct (Fig. 2a), sensoria on antennal segments of female two or three lobed and arising from one pore (Fig. 3a) *Mycophila barnesi*

   Tarsi without scales, empodium rudimentary (Fig. 2b), sensoria in form of broad plates arising from several pores (Fig. 3b). *M. speyeri*



(*a*) Wing of *Heteropeza*.



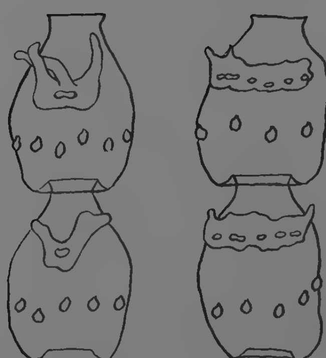
(*b*) Wing of *Mycophila*.

Figure 1.

(*a*) Tarsi and claws of *Mycophila barnesi* (showing empodium between claws and scales).

(*b*) Tarsi and claws of *Mycophila speyeri* (showing rudimentary empodium and no scales).

Figure 2.



a) *Mycophila barnesi* (*b*) *Mycophila speyeri*

Figure 3.

Antennal segments showing typical sensoria. (Hairs are represented by their bases only).

(*a*) *Heteropeza sp.* (*b*) *Mycophila spp.*

Figure 4.

Sternal spatulae of pupa-larvae.

In the case of the larvae it is only possible at present to separate the two genera in the sexual or " pupa-larva " stage (see next section) when the " anchor process " or sternal spatula is present. This organ is trident-shaped in *Mycophila* but spear-like in *Heteropeza* (Fig. 4). A good general indicator of the genus involved is larval colour—*Mycophila* are orange and *Heteropeza*, white. A word of caution is necessary here, however, as work on *Miastor*, a closely related genus, has shown that white larvae can become orange under certain environmental conditions. We have not observed this phenomenon in *Heteropeza* as yet.

Biology.

The only biological data on the paedogenetic Cecids available in the literature is contained in papers by Harris (1923) and Gabritschevsky (1928) on *Miastor* and studies on *Heteropeza* by Harris (1924, 1925) and Ulrich (1936). Although *Miastor* has only occasionally been associated with mushrooms in the U.S.A. and is normally found under bark of Birch, Chestnut and Oak, the published papers do provide an interesting insight into Heteropezine ecology. Gabritschevsky recognized four habitats:

(a) Below decomposing bark on wet trunks the larval colonies were white and paedogenetic.

(b) On dried trunks, where the desiccated bark was cracking, colonies consisted of white larvae with a few orange and " pupa-larvae."

(c) In completely dried-out trunks, where the bark no longer adhered to the wood, only orange and " pupa-larvae " were present.

(d) In mid-winter most colonies consisted of orange larvae with occasional white forms.

The orange forms referred to have large hypertrophied eyes and strongly developed migratory instincts. A few larvae with atrophied eyes have been found in our *Heteropeza* cultures and it is possible that a similar " resting-stage " may exist in that species to survive unsuitable conditions, but without the orange-pigmented fat-body. The inference to be drawn from the fauna of these subcortical habitats is that the occurrence of pupae, and hence adults, is governed to a large extent by external environmental factors, e.g. dry conditions impeding fungal growth and hence larval nutrition.

Studies on the life-cycle of *Heteropeza* have only been made in cultures of various fungi. Ulrich used a *Penicillium* sp., while Harris allowed the larvae to inoculate agar plates with their own contaminants. In our work, a successful technique for sterile rearing on mushroom mycelium has been developed by surface sterilisation of larvae in 5% formalin before introduction into pure mycelial cultures.

The life-cycle is, of course, complicated by the phenomenon of paedogenesis but, in outline, the life history is as follows. Fertilised females are capable of laying about four eggs (Roeder 1953) but according to Thomas (1942) *M. americana* lays as many as twenty. The only information on the habits of the adults is Speyer's note on *M. speyeri* (Barnes 1926) where he observed that both males and females, kept in

a tube of soil with mushroom mycelium at the bottom, burrowed down to the latter, though no eggs were found. He described their flight as rapid but erratic, and observed that they were strongly attracted to windows and lights. The eggs hatch into undetermined daughter larvae (Fig. 5a) which themselves become paedogenetic within about ten days. These daughter larvae have no sternal spatulae and the eye-spots are touching. Several practical growers have confused the dorsal eye-spots with sternal spatulae, which are elongated and on the under side of the body. In these paedogenetic larvae, eggs develop within the ovaries until a variable number of daughter larvae is produced; these are set free into the body cavity where they destroy the tissues of the mother and ultimately escape through her body wall leaving no more than the dead skin. The young larvae are visible through the integument of the mother from about the seventh day. The number of daughter larvae produced varies very little even in long continued paedogenetic lines. Ulrich records a mean of 16 larvae per mother over 262 generations. Our own figures average about 7-8, which suggests that mushroom mycelium is not such a preferred habitat as *Penicillium*. Ulrich also demonstrated the importance of nutrition in relation to the number of larval offspring produced by paedogenetic mother larvae, by keeping cultures on agar media of different dilutions. Using saccharose and maltose agars the mean number of daughters per mother was 13.9, but on media diluted 20 times, only four daughters were produced by each mother.

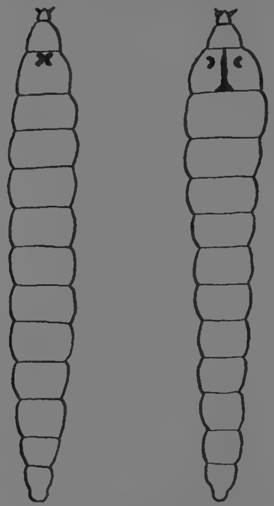


Fig. 5. Larvae types of *Heteropeza*.

(*a*) *Paedogenetic* daughter larvae (showing touching eye-spots) (left.)

(*b*) Pupa-larvae (showing separated eye-spots and (sternal epatula) (right.)

Heteropeza will normally continue paedogenetic reproduction indefinitely with optimum food and environmental conditions and a temperature about 84°F. Should conditions predetermine the production of adults, a special paedogenetic mother (known to the Germans as a " Puppenmutter ") is formed. These produce 3 to 5 sexual or " pupa-larvae " having their eyes widely separated (Fig. 5b) and possessing imaginal discs (which ultimately form adult organs) on segments 3, 4 and 5. After 4-5 days the sternal spatula appears ventrally on the second segment and rapidly darkens. The sexual larva eventually becomes an orange pupa, with external legs and wing buds, and emerges as an adult fly after about 5 days.

As is well known, very high larval populations can develop in mushroom compost. They normally remain hidden below the surface, although they will often swarm on top of the casing, following watering. During this swarming, they may fall to the floor, where they jump about and eventually become aggregated together in writhing masses about ½ in. in diameter. The significance of this migration from watered beds is not clear, for larvae will withstand submergence in water for several days, but Moreton (1956) has suggested that water may facilitate migration from overcrowded conditions. Our own culture tubes certainly support the hypothesis of migration within fine water films, although whether this explains why Cecids seem to have become more troublesome with the widespread use of peat—a medium with high moisture capacity—is a conjecture. Atkins (1956) reported growing twenty successive crops, cased alternately with peat and soil, and Cecids only appeared on the surface of those beds cased with peat. He added, however, that occasional swarms on soil-cased beds were known to him. In the few outbreaks we have studied, it was noticeable that larvae seemed to appear in the compost first, and later to leave it almost entirely for the nodules of peat in the casing layer.

There is no direct evidence in the literature that cecid larvae feed on the mycelium, but our sterile cultures definitely show that they are capable of completing their life-cycle on this food and there is little doubt that they cause most of their damage in this way. In practice it is difficult to sample damaged beds and correlate cecid populations with loss of mycelium, owing to the invariable presence of eelworms. Cecid larvae will also attack mushrooms and we have often observed them in abundance associated with cases of bacterial pit. Unsterilized larvae leave strong bacterial paths across agar plates, so that it seems highly probable that they serve to spread the disease and possibly, on occasions, actually introduce it. More normally damage to mushrooms is done by larvae burrowing in the tissues of the stem, where discoloured, slimy streaks, often with a shredded appearance, occur. They also cause the edges of the gills to wither, as if nibbled—this is probably due to collapse of the hyphae which the larvae have been observed to suck. A bacterial slime is sometimes associated with this type of damage.

Factors Tending to Terminate Paedogenesis.

It is well known that Cecid larvae are difficult to kill, whereas the adults readily succumb to insecticides, so that a considerable advance in control methods might be feasible if a method of terminating paedogenesis could be devised.

One of the earliest theories was that light initiated pupal production, but Harris (1923b) showed that, in fact, light was slowly lethal to the paedogenetic forms, thereby increasing the proportion of the " pupa-larvae" in a constant population by artefact.

Most workers have concluded that crowding and poor nutrition are effective, although it has not so far proved possible to isolate the effects of these factors. Certain indirect evidence that it is actually a nutritive rather than a population effect has been obtained by Ulrich. He introduced 10 daughter larvae into fungus cultures which had been growing in Petri dishes for from 2-12 days. Of the larvae placed on

2-day fungal cultures, only 0.5% of the 2,058 larvae became pupa-larvae, whereas in 12-day fungal cultures 42% out of 340 larvae pupated. In another experiment, he had two groups of seven paedogenetic cultures on *Penicillium*. To one group he added yeast and raised the mean number of progeny per mother from 15 to 22 and, at the same time, reduced the proportion of sexual larvae in 12-day cultures from 42% to 23%. Using largely expended agars from earlier cultures he inoculated some with very heavy and others with light concentrations of fungal spores. The heavy spore inoculates, presumably resulting in a very weak mycelial growth, produced 42% pupa-larvae whilst only 5% pupated on the stronger mycelial growth.

Harris (1925) found that it was possible to cause a reversion to paedogenesis of sexual larvae, produced in crowded cultures, if they were removed to fresh cultures before the anchor process had pigmented; an observation we have confirmed in our own experiments.

Our own limited observations suggest that there is quite a complicated balance involved. If a culture becomes starved slowly then the majority of larvae will become sexual, but in very crowded cultures in which the change from abundant food to starvation levels occurs quickly, the whole population seems to go into quiescence or die with very few sexual forms developing.

All workers have agreed that, in *Miastor*, conditions of abundant food, high humidity and even temperature cause unlimited paedogenesis but Harris (1923a) and White (1946) found that there was a tendency to a seasonal periodicity in the production of sexual forms. Both workers found more pupa-larvae in spring and early summer.

Gabritschevsky (1928) made various tests on methods of artificially promoting development of " pupa-larvae " and was successful with thermal shock—putting slowly growing cultures at 40-50°F. suddenly up to 85°F.

White (1946) and Reitberger (1940) have studied the chromosome cycle and demonstrated that there is no cytological difference between paedogenetic and female sexual larvae, so that the change is probably environmentally controlled.

Effect of Temperature on Cecid Larvae.

To establish that the temperatures commonly reached at peat heating and composting are satisfactory for killing cecid larvae, we have made tests on the thermal death points of two species. Larvae were exposed in vials within a thermostatically controlled water bath for one hour. Mortality was assessed 24 hours later. *M. barnesi* succumbed at 99°F. but *Heteropeza* did not die until the temperature reached 113°F.

Attempts have also been made to gather data on the speed of development of paedogenetic larvae at different constant temperatures. At higher temperatures, colonies in apparently the same environmental conditions behave irregularly, some developing very rapidly and others becoming senescent. These effects are probably indirect in that growth of the mycelium is retarded under extreme conditions. However, the mean values in Table I show that high temperatures tend to speed development, but less rapidly than in other insects, and reduce the number of offspring.

Table I
Effect of constant temperatures on development of paedogenetic *Heteropeza* larvae.

Temp. °F.	Length of Paedogenetic generation (days)	No. young/mother
69·8	9·5	10·2
76·3	8·5	8·0
81·4	8·6	7·5
85·1	8·1	7·0

Points of Interest Raised by Growers.

Undoubtedly the source of infection is a matter of primary importance and in view of the known habitats of *Mycophila* spp. it is possible that some larvae can be introduced with the compost. In our faunal studies on fresh compost and horse manure no mushroom cecids were reared; but even if a few gained entrance in this manner it seems unlikely that they would survive peak-heating as few pockets of compost must fail to reach 110°F. The discovery of *Mycophila barnesi* in peat and *Heteropeza* in peaty soil suggests that unsterilized casing may be a source of infection. The capacity of the latter species for burrowing within the bed-boards for up to ½ in. (Moreton *in litt*) must ensure its survival on many farms. It is possible that the apparent success of Heron's (1957) control by treating the boards with Sodium pentachlorphenate is due to the killing of the mycelium of wood-rotting fungi within the wood. Some direct larval mortality also results from the use of this fungicide.

With any of the species, infection may occur by adult flight, and it is of interest in this connection that we have taken *Heteropeza* in the light-trap 11 days after peak heating, so that emergence from the compost in that short period was most unlikely. There are no data on the powers of flight of adult Cecids, but certain growers have reported that they seem to be extremely local in distribution, even when farms are only a mile or two apart. Real progress here depends on our ability to recognise their preferred natural habitats and a possible lead has been given by a grower who reports a very local and serious infestation where a heavy concentration of decaying Elder (*Sambucus nigra*) is present in the vicinity. As spent compost is often teeming with larval cecids the location of its disposal will also have to be investigated.

Data derived from our Questionnaire were not particularly helpful as, with only 82 replies, the numbers involved in any comparisons were too low. For what they are worth, the following points emerged:

As one would expect, incidence of cecids was less among tray growers than shelf growers owing to the shorter cropping period;

Composting methods appeared to have no influence on cecid occurrence;

The most interesting indication was given by comparing temperatures reached at peak heating. 45% of the growers who attained temperatures of less than 130°F. experienced Cecids (18% seriously)

whilst 68% of those reaching 131°F. and above had attacks (32% serious). It is suggested that this greater incidence of attack under theoretically more hygienic conditions may be due to the elimination of some natural control factor, e.g. eelworm or fungus.

Present Research.

Our immediate investigations are concerned (i) with studies on the causes of cessation of paedogenesis, facilitated by artificial rearing techniques to permit variations of nutrient level, and (ii) the discovery and ecological study of natural population reservoirs.

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DISCUSSION:

We have found diazinon effective against all stages, but the great trouble is of course to get the insecticide in the right place. It is obviously better to get your insecticide into the compost at the start, before peak heating, and we want to find out how much truth there is in the statement that there is inactivation of insecticides through the reaction of small quantities of ammonia during peak heating.

Our first reaction was to use not insecticides but repellants. There are certain medical difficulties with repellants such as are widely used as anti-midge creams; they are not very safe on the eyes. But there is obviously a possibility here; if you have an impregnated blanket and people have to push it aside you are going to get far less ingress than you do normally.

A very interesting feature emerged from the Littlehampton Questionnaire, and that was that on the plants of those who peak heated higher and longer than the rest were found the greatest proportion of serious outbreaks. I think that one of the things involved here is a sort of biological truism, that you are creating a vacuum if you are too efficient; and if anything gets in the door you've had it!

We are in process of examining our whole last year's fly trap catch, to see whether phorids in particular are more infestive at the beginning or end of the crop, and what differences there are in the seasons of the year. You only get phorids in numbers when the mycelium is running. You can leave your compost open as long as you like and you'll never get phorids until you spawn it.

LIQUID ACTIVATORS FOR SYNTHETIC COMPOSTS

S. E. LAKE
Plant Protection Ltd.

It was a discussion between Mr. Fred. Atkins and Mr. T. Ainslie Robertson some four years ago that first set me off indirectly on a search for a liquid activator. I should make it quite clear that what I am about to say refers to work that I have carried out in a private capacity.

Early discussions with Mr. Atkins, Dr. Edwards and others indicated a general interest in Urea which, after extended trials at Yaxley and elsewhere, proved less attractive than we at one time envisaged.

Since those days we have proceeded along a road full of developing interest and encouragement. But, may I make it quite clear at this early stage, this review is, as far as I am concerned, the first chapter on the liquid activator technique of composting.

It was not until late June of this year that sizeable trials were laid down using a modified formula. It was not until mid-September that cropping on the first trial began.

We are I feel quite sure at the beginning of a technique which might well contribute greatly to reducing the present production cost of this crop.

My story to-day covers not so much the production of mushrooms from liquid synthetic composts, but its economy in preparing the compost. I am suggesting that cropping is really a matter for grower co-operation and not for the enthusiastic experimentalist.

Synthetics are used—like stable manure—with varying success. Present-day synthetic compounds cover a wide range of qualities. Probably the best all round dry synthetic is the MRA formula. It is equal in cropping power but more uniform in composition that stable manure. It is estimated that some 20% of mushroom production in this country is by synthetic compost of one type or another, plus the use of synthetics as boosters.

It is generally agreed the MRA formula offers certain advantages over any other dry synthetic. It has, for instance, a stable analysis. It is essential that a liquid activator should maintain the same nutrient value as that in the MRA formula.

A liquid activator seems to have much to offer those already interested in synthetic composting and sufficient attraction to arrest the interest of other growers. It is here that economy in production comes forcefully into the picture. It offers economy in application, economy in material cost and economy in labour for composting.

The Formulae

Experience over many years with liquid plant foods indicated Urea as a likely source of N. It is competitive in price, completely and readily soluble and a highly concentrated form of N. Soluble sources of P and K are found in Monammonium Phosphate and Potassium Nitrate and the Trace Elements can be added in accordance with the MRA formula, Calcium Carbonate and Gypsum being added at the last turn in the traditional manner.

Extensive trails over a long period on a number of sites proved that Urea was not a suitable source of N. In the first place it was responsible for giving off embarrassing quantities of free ammonia. Amounts were such that they affected operators at the time of turning. Secondly, bacterial activity was slowed down, particularly in the winter months, which in turn slowed down fermentation. Apart from these drawbacks crops varied from 3 lb. + to ¾ lb. per square foot over a three months' cropping period.

Perhaps one could claim some relations between these crop returns and those from stable manure—but whatever view is taken it must be one of caution where Urea is the source of N. However, with this knowledge, other sources of N have been tested, with the result that Urea is almost excluded from the present-day formula.

Economy in Application

Hand application of dry synthetics calls for rather exacting placement and accurate distribution of the 3 to 6 cwt. required per ton of straw.

Mechanical application of dry activators is not without human error of judgment.

The MRA formula requires 4¾ cwt. per ton of straw and is recommended to be applied in two parts. Other synthetic formulae require up to 6 cwt. per ton of straw.

In late June of this year I laid down four trials, two being based on liquid activators, one a mixture of liquid activated straw and stable dung, and the fourth entirely stable dung; but we will return to these trials for more detail later on.

Meanwhile, let me describe in a simple way, illustrated by two slides, just how foolproof and economic it is to apply a liquid activator evenly and economically to a given quantity of straw.

It is taken for granted that the first essential in synthetic composting is to thoroughly wet the straw. There are a number of ways already in practice. Equipment may be expensive, placement of water must be exacting, results may be variable.

By trial and error I have found the most practical method is to stack the bales 3 high, run a line of 'Solu-Ply' (samples exhibited) —a 2¼″ lay flat polythene tube perforated by 4 holes $\frac{1}{32}$″ at 7″ spacings, costing 3d. per foot—the length of the bales. These are string drawn bales averaging 60 per ton, stacked 3 high = 10 yards.

Water is turned on to give a throw of water 12″ on each side of the tube. This gives 17 gall. per hour per yd. of tube = 170 gall. per hour on 10 yds. To apply 600 gallons water, it would take 3½ hours.

It is obvious to those who have experience of wetting straw that this amount cannot be applied at one time, but by the simple approach of enlisting the aid of a time switch attached to the stand-pipe and setting the clock to switch on for 5 minutes in each hour, the process is automatically controlled and the wetting is completed in just less than 48 hours, or if a 2½-minute period is desirable, 90 hours—in either case the labour costs involved in wetting the straw are negligible and the equipment apart from the time switch less than 10/-.

Adding the Activator

After adding some 200 gallons water in this way the straw becomes absorbent. At this stage the Activator can be added. It can be applied through the 'Solu-Ply' by the aid of an accurate dilutor, such as the Keylutor.

This machine is designed for this purpose—with a special jet to give accurate dilution.

The Activator

The liquid activator used in these trails is identical in *nutrient value* to that recorded for the MRA formula, but omitting Calcium Carbonate and Gypsum. It is contained in 1 cwt. of soluble powder. This is dissolved in 36 gallons water and applied automatically by the Keylutor at a dilution rate of 1 in 10.

The time switch can be suitably controlled and regulated to prevent loss of surplus drainage from the pile. I found 3 minutes in each hour to be sufficient to penetrate the straw without waste.

In this way we get 600 gallons water per ton, 200 preliminary, 400 with activator, all applied automatically and with minimum labour costs, but accurately and evenly. Additional quantities of water may be added if required at the time of turning, as can the required amounts of Calcium Carbonate and Gypsum.

Economy in Labour

It will be obvious that substantial savings can be made with labour—whilst the practice of synthetic composting by the liquid process becomes a much cleaner proposition with a complete absence of objectionable dust which frequently gets caught in the wind.

The Tests

The tray method of growing has been adopted for each of the trials—the traditional fish box is being used for convenience.

In order to compost a sizeable heap, approximately 1 ton of straw was used in each of the synthetic treatments, but only sufficient compost to cover 250 sq. ft. of growing area was used in each trial.

Test No. 1

This was commenced on 28th June, 1957, along the lines indicated. On the fourth day the temperature of the straw in the bale had reached 120° F.

The following day the bales were shaken out and stacked, approximately 100 gallons of water was added.

Earlier experience with liquid activators indicated the need for a substance to give ' body ' and stimulate bacterial activity, so in this test a mixture of 50% activated sewage and 50% Calcium Carbonate—1 cwt. in all—was added at the time of shaking out and stacking.

The pile was trodden down firmly all over—baled straw was placed round the sides and the top covered with polythene sheeting.

Three days later the pile temperature was 135° F., reaching 145° F. on the fifth day.

The first turn—on the 6th day—when the temperature reading was 145° F. indicated the need for more water—approximately 100 gallons were added. There was no sign of free ammonia and everything appeared to be " according to plan." At this stage there was ample evidence of firefang. The heap was again covered, sides and top as before.

Two days later when the temperature reached 130° F., the polythene covering was removed for 12 hours, for observational purposes. It was noted that a thin wisp of vapour came from the heap.

On the 6th day the heap took a second turn, temperature 145° F. A faint smell of ammonia was noted. At the bottom centre there was evidence of anaerobic conditions.

The pile was again firmed down tightly round the sides, but not in the centre, and covered as before. For the next 6 days its behaviour followed the same pattern as before and on this day it was shaken out and filled into trays.

No peak heating facilities were available. Spawning followed 3 days later, casing with 50% peat-and-chalk 12 days later, and pinheads were noted on 6th September. At the time of writing these notes (14th Sept.), the quality of the crop is high but the weight of the first flush is not heavy.

Test No. 2

This differed from the first in that no activated sewage or calcium carbonate were added—other treatments were identical. Throughout the processing the temperature was either lower or irregular throughout the pile. At each turn it was noted the nature of the compost had a lightness about it and there seemed to be a lack of ' body ' in texture. It was decided to give this pile four turns, filling taking place 32 days after the liquid activator was applied, 12 days longer than Test No. 1. There may be a number of local factors causing this long composting period.

50% of this pile was filled into trays, the remainder at the time of the second turn was mixed w/w with stable manure to make,

Test No. 3

This pile behaved in a normal manner. There was no difficulty with fermentation and after two turns in 12 days (each pile from which they were taken having had one turn prior to mixing) was filled out into trays. Pinheads were noted on 13th September, four weeks after filling, the same period as Test No. 1.

Test No. 4

For manner it was considered that a comparative test, using stable manure only, would add interest to the range. There is nothing significant about this test except the cost. It was filled out at the same time as Test 3, but so far shows no outward sign of cropping—unlike the other three it was perhaps on the wet side and it was noted that mycelium run was slower prior to casing.

Liquid Feeding

I believe many trials have been made to improve growing crops by the application of various nutrients in dry and liquid form, none proving of much real value. Further small-scale trials in which attempts to feed a growing crop in this way are I think worthy of mention.

Having decided upon a formula along the lines of that of the MRA, but which is readily soluble, it seemed the obvious one to choose.

Three pounds were dissolved in 1 gallon of water and applied at 1 in 100 gallons, application being made whenever water was needed. The results at this early stage appear encouraging.

In Test 1 twelve trays were treated in this way. Eight of the twelve were the first to crop out of a total of 85 trays. A similar earliness is found in Test 3, and sufficient interest is aroused to pursue this technique on a larger scale.

Summary

Let me repeat what I said earlier, the technique of composting by liquid activator system is yet in its infancy, and one cannot draw conclusions, good or bad, on the strength of what I have outlined in this paper. It is, however, a subject which bears discussion. The fact that it may reduce cost of production is of major significance; the cost of labour and stable manure are at a premium.

The liquid activator system shows an attractive saving in both items. It must also bear some consideration in terms of activator material cost.

The behaviour of the pile is similar to what we are accustomed to with other methods of composting. The drawbacks and disadvantages

of Urea are apparently overcome by the revised formula, at least in these trials, but one would be wise to hold opinion until after winter trials are completed and reviewed.

Trial No. 1, which included bacterial activator and calcium carbonate, indicated a quick responsive compost coming into crop within 5 weeks of filling out. Test No. 3—the mixture—cropped in about the same time.

A significant feature of this test is the increased growing area the mixture offers. The full facts have yet to be assessed.

Another feature is the quality of the crop. Here I should perhaps say it was manure spawn that was used throughout.

If this review is of sufficient interest to encourage a few producers to put down small-scale trials, I can promise to give adequate support from the technical viewpoint.

" **We need** a standard formula for composts, a greater knowledge and standardisation of casing materials, more knowledge and understanding of air movement, and more research into pest and disease control," said Fred. C. Atkins at a mushroom conference at Cambridge.

Commercial Grower, February 21/58.

MRA SYNTHETIC COMPOST

M. C. LUXMOORE
Snowcap Mushrooms Ltd.

The basis of our growing is undoubtedly founded on compost and for the most part this in turn has been dependent solely on horse manure. In my case in the period that preceded the last war it arrived in railway trucks, from a terminus in London. The task of digging it out hot and steaming will live in my memory, and what surprises were to be found in the load from Stepney! More often than not the wagons had been on rail for a week, and a fair amount of what we now know through our scientific friends as anaerobic composting had already taken place. It was a commonplace to add a quantity of straw to stacks made with this type of manure, and the reek of ammonia at off-loading could be over-powering. The straw added bulk and somewhat diluted this formidable delivery.

I can't think that many of us are driven to such measures these days. Where like supplies are found, with the addition of knowledge that is now at our disposal, I have no doubt that heavy crops result. Indeed the grower consistently producing heavy weight has, in my experience at least, always had access to a favoured supply.

It is obvious that, with many less working horses and a great increase in the number of growers, a real crisis is on our doorstep. This may be slightly offset by a new enthusiasm for riding, but this cannot be much substitute for all those concerns that have said good-bye to their horse transport, and have taken to mechanised haulage. The majority of us are forced, not as in the days prior to the war to " water " our compost down, but to seek some means of increasing activity by a boost, or as in my particular case by embracing an entirely new technique.

I must at this juncture add that I am of course aware that great success has attended the use of pig manure as a basis for mushroom crops, but for the grower lacking the attachment of a fair sized piggery there seems real difficulty in obtaining supplies, and when I have enquired, either the pig manure is being used by the farmer himself, or the price asked is uneconomic to us though doubtless not to him.

Five years ago these considerations were very much in my mind and I therefore approached Fred. Atkins who had already stepped into the field of synthetics, and indeed was justifying their use in conjunction with our own Research Station at Yaxley under the directorship of Dr. Edwards. Here at Yaxley, Noble Mushrooms Ltd. were commercially in full swing, and had turned their back on the horse with as much assurance as the hauliers were exchanging the quadruped for the combustion engine. With the unstinted kindness of Atkins and Edwards, and the unfailing patience of Noble in growing matters, a compact and new farm was built and set down at Yaxley within a few yards of what is now the deceased MRA buildings.

At this time too something of a revolution was imminent in the mushroom growers' world. The inflated prices during the war years were on the wane. The price of building was very much on the rise and a good deal of consideration was being extended to the rigid cutting out of time lag in growing houses. Very quick and responsive spawns, such as grain and manupel, were being accepted and proving successful. The tray system in this country had already been launched with the accompanying rumblings of approval and disapproval of established shelf growers, and the race for existence was starting to move into a gear that was foreign to me at least.

I wish to make it clear that this insistence on speed is a growing-space problem and within reason not applicable to composting itself. Composting is primarily a problem of labour, and although space must be available it is cheap and easy to provide and is quite unlike space in a heated and insulated growing house. Certainly mechanisation in some form is demanded but provided the same number of turns are necessary for an eight day compost as for a twenty-seven day one, I am not persuaded that there is virtue in the former, always allowing that the resulting crops are similar in weight. The essential then is not so much speeding up the act of composting but speeding up of what takes place in the house itself.

The ready availability of fresh composting material must be necessary for a strict routine to be observed. I have reason to admit that the practical side of an MRA compost is far from easy to grasp. To balance the matter let me say that the knack once acquired saves many headaches, and if you start small and combine skills already well known to you with pointers I will attempt to give, you can achieve success as readily as with horse manure. Few people will emulate the clarity and ease with which Rasmussen has diagnosed the essentials of composting. It seems formidable that he should do so, in a tongue foreign to him. He tapped the very vitals of mushroom culture and in respect I would not only admire, but also wholeheartedly support, his contention that " here is where we must seek success or failure." The composting is the alfa and omega and the rest of the procedure is of comparatively small account.

If this short address fails to warn you of pitfalls I myself have encountered both you and I will have wasted our time. If successful you will at least start with information that might otherwise have been learnt through painful experience. Let it then be accepted that up to a

point we are being driven to the use of synthetics not only by the decreasing supplies of horse manure, but also by the ever increasing need for a quick turn round. The situation is a paradise for the statistician, and the very fact that we talk of ourselves as an industry indicates the acceptance of factory line production such as is already in use with pigs and poultry.

This is neither the place nor time to discuss the chemical details of the activators we use. They are quite well known and have been amply proven. Dried blood provides the bulk of the issue and may I here stress that any deviation from "dried blood" is apt to show itself unfavourably when the crop is taken. Work is progressing on substitutes but until on a field scale they are proved, my advice is to stick rigidly to the book of words. The temptation is to try something cheaper in place of the blood but I know of no example where a favourable comparison can be made. I am not saying that there have not been good crops taken with a substitute ingredient, but one swallow does not make a summer, and until a full series of field crops show as good and consistent results as dried blood, it has at the moment no equal. A cheaper and as reliable a medium will be hailed with some enthusiasm but the time as yet is not ripe.

Bradford Fertilizer Co. Ltd. supplies our Activators. We are apt to overlook the difficulties in other industries, being so beset with those of our own. There are skills in the collecting and drying of blood that we know nothing about, and this firm has done this particular work for many years with spectacular results. I make no apology for mentioning their name; I am not paid to do so, nor is this the B.B.C. The quality of their activators is unassailable, and the organisation to get them to the grower has, as far as we at Snowcap are concerned, never failed. They also possess machinery whereby very small quantities of trace elements are distributed evenly through a huge bulk of other ingredients. This allows us to leave the mixing entirely in their hands, and it is far better to order the MRA Activators No. 1 and 2 already bagged and mixed than to attempt the mixing ourselves. This allows us to keep a month's stock in our store and it is always possible to put a synthetic stack down on any chosen day.

The second necessity is for baled wheat straw and stocks of this are kept in the open near to our turning shed. Our first problem when laying or putting down a stack is thoroughly to soak the requisite number of bales. When dry they are easily moved and are frequently in use as wind-breaks or compost frames before being committed to the Wetting Bay. We all accept that wheat straw is the correct type of straw to use but the varieties are many. Until some research is done in this matter we content ourselves in assuming two classes,

(a) Long straw bales,

(b) Combine or short straw bales.

There are I take it a good many sub-divisions of Combine straw, and after five years of composting synthetics I avoid it in spite of the smaller size of bale (a great help when moving about the place), and smaller straw length which would suit us admirably. There is at least one of

our members (possibly present), who is first and foremost a straw merchant. He no doubt could enlighten us on this subject but suffice it to say that the physical make-up of these two types of straw differs. The combine is of a stiffer and stronger variety. A study should be made on this particular point and might have far reaching results.

I am wondering whether you reject some horse manure on the grounds that the straw is of the combine variety. We certainly do just that, and are most particular that combine straw is not used in our stacks. The fibres seem much tougher and refuse to break down into the smooth, soft finished product that we require. Even after the sweat out the straw remains harsh and prickly and the resultant crop nearly always a poor one. The spawn run however does not seem to suffer and laps its way through the compost in accustomed manner. Could it be that some failure of yours (and we all have them) with horse manure might be attributed to type of wheat straw or does the horse reject it in any case as too harsh for bedding?

Now for just one moment I must revert to house structure because it also has a direct bearing on the quantity of straw bales we shall need. I hardly dare tell you but I am a " shelf grower". This won't have much bearing on synthetics as such but I must at once admit to it, so that quantities I give you will have justification, and allow you moderns to make your conversion from old-fashioned to new. Each house is four shelves high and the inside dimensions are roughly 46ft x 15ft x 8.5ft. Shelves are 7-8 inches in depth and each of the eight shelves is approximately 160 sq. ft. in area. Briefly as possible then a growing house contains some 1,280 sq. ft., and there are thirteen of them. Peak heating or sweating out is achieved in winter by subsidiary heat, but takes place with little persuasion in the summer months.

The cycle of a crop from filling to refilling is thirteen weeks and this allows us to take four crops from each house in the year. The procedure in each house varies as little as possible. Filling to spawning six days. Spawning to casing 10 days. Casing to first pick 19-21 days, and picking for approximately 48 days. This leaves a week for throwing out and internal economy or sterilization. This schedule dictates the number of composts always in preparation, which in turn dictates the size or area of the Wetting Bay. We are now almost consistent with the quantity of straw bales needed, and for our particular area we use 88 bales of long straw per house. (24 to one ton dry weight). If on filling the number has not been sufficient it serves as a reminder that our composting is not up to standard. The quantities of activators 1 and 2 needed per ton of straw can be found in *Mushroom Growing Today* by Fred. Atkins and also in the instructions issued by the old MRA. The unit used in both cases is one of a thousand square feet of bed area and as in our case adjustment has to be made accordingly.

The procedure for preparing a compost is invariably the same and has taken some 150 crops to establish. The first consideration is thoroughly to soak the 88 bales of wheat straw. A variety of methods have been tried and at long last we have accepted sprinklers of the Rainmaster variety which do the work admirably. They are not only

comparatively cheap as opposed to piping, spray lines and the like, but they are far easier to take down and clean out. A jelly like substance is constantly being formed by the action of the water on the straw, and bits and pieces of straw tend to get into and choke small sprays. The Rainmaster is a rotating sprinkler such as is used for lawns in a dry summer and can be taken to pieces, washed in warm water, and refitted again in a very few minutes.

The bales are stacked in the Wetting Bay two high. It is advisable to keep to this height as, once the bale is soaking, it is heavy and cumbersome to move about. The floor of the Wetting Bay is sloped so that the liquor from the bales, which soon becomes dark brown in colour, runs into a tank. The tank is divided into four compartments and the water allowed to run from one to another passing through a series of filters, before being re-circulated by electric pump. Once a month these tanks are cleaned out with Tide, the filters which consist of wire grating, scrubbed out, and foreign bodies removed. The water also passes through a compartment filled with gravel and this generally takes care of small bits and pieces of straw.

In cold weather we are able to introduce the nozzle of our portable boiler and push steam into the tanks to warm the water. Surprisingly soon the straw itself produces heat and the shell-like cellulose on the outside begins to soften, break down, and become pliable. The bales are subjected to four Rainmasters for three days. The pump is then switched off for 24 hours to allow fermentation to start. The pumps are switched on again for another three days and the bales are completely saturated and warm on being broken open. One at a time, these bales are taken by small truck to the composting deck. By now their weight has greatly increased and weigh about 3 cwt. The wires holding them together are clipped, and the contents of each bale passed through a straw chopper.

Dry straw bales are made to serve as walls two bales high, and the chopper shoots the soaking straw into the space between them. The straw is built up about 18 inches high and Activator No. 1 is spread on much as jam in a sandwich, at the rate of approximately one 3-gal. bucket to the bale. This is repeated, each layer of straw being trodden down tight until the requisite number of bales has been used. In our case, for 1,280 sq. ft. the number of bales is as I have mentioned 88, and will cover an area of 36ft x 9ft x 2 bales high.

We deal with the compost in quarters, making our first quarter with 22 bales, introducing the Activator, and treading it down. The second quarter is then joined on the dry bales forming the frame having first been erected. At " filling time " we know that one quarter should fill the two bottom beds, the second quarter the next two and so on. The house in this way is consistently filled throughout.

This stack is now left to " cook " for six days. This stacking process is not looked on as composting at all. All we are doing is making a substitute for horse manure and our day's work in completing the stack has nothing much to do with the principles of composting as

we know them. A first turn is now given, the whole being turned into a stack 36ft x 10ft x 4ft. Water is added where necessary, the sides of the stack are firmed, the bales are disposed of and no tramping takes place. The principles follow those with which you are conversant. A second turn is given after a further six days, the heap often but not always being now split into two heaps of 36ft x 5ft, instead of one heap of 36ft x 10ft. Again procedure in turning is normal, and after five days in this stage a shake up is given through a turner, the neat piles being turned into loose heaps and Activator No. 2 being added. The following day the compost is filled.

The process has taken 18 days from start to finish, but remember we do not set off with horse manure, and actual composting time is in reality 12 days. It is as well to make this clear to allow comparisons between long composting, short composting, and synthetic composting. Once in the growing house a peak heat is attained, and the familiar principles applied to horse manure are followed.

You may wish me to end with a rough estimate of man hours. With our number of houses, 13, and keeping strictly to 13 weeks from " putting in " to " taking out " we are able to do each major operation once a week, and a set day is provided. Each Friday for instance we lay down a stack and any necessary finishing touches are done on a Saturday morning. This is the heaviest and longest job of all (4 men). Mondays we empty a house (3 men), spawn, and give a shake up (3 men) to the stack to be put in on the morrow. Tuesday we devote to filling. Wednesday cleaning down the emptied house and a second turn (3 or 4 men). Thursday dipping bed boards and spraying out the empty house and a first turn (4 men). Picking should also in theory be even, and each week we should by rule of thumb pick a first, second, third, fourth and fifth flush. Those familiar with the "Atkins Pattern", and heat waves in summer, know that this routine is easily upset.

However, broadly speaking, we are able to keep to this schedule, and since the inception of this routine six months ago, have been able to crop at a rate of nine lb. per annum per sq. ft., or an average per house of $2\frac{1}{4}$lb. in seven weeks picking. These figures apply to mushrooms packed ready for market, and take no account of stalks. Tray growers will find the number of crops lower than they themselves achieve, but it must be borne in mind that we see the crop through from start to finish in a single house, and no sweating-out houses are in operation. The yearly figure will we expect be lower as the Atkins Dip makes itself felt but, should all proceed normally, the total poundage per square foot from the farm throughout the year will be between 8 and 9.

Although I have sketched in a programme and given main jobs and figures, there are of course numerous other activities besides stacking, turning, emptying. Our desire is to combat boredom by variety. Key men are (1) a chargehand in authority over all composting and he is never out of the turning shed, where two composts are always in pre-

paration save over weekends when there are three. The other charge hand is concerned with watering, spawning, and casing in the growing houses. All the remainder of the staff are interchangeable though women are not of course used for actually composting.

I hope in this brief summary I have been able to convey to you something useful about the application of synthetics. Primarily I regard them as a great aid to full capacity production, not only for their stable cropping qualities, but also for the ease with which they can be stored, and therefore the certainty with which a very tight programme can be carried out. But do not think that there are no setbacks and that a programme out of adjustment can be mighty difficult to readjust. What happens over Christmas or a Bank Holiday?

And lastly: I have not dared suggest that synthetic growers' crops are less susceptible to disease. A semi-scientific approach has failed to subdue a certain timidity, and superstition is my constant companion. It seems however a possibility that strongly growing crops are least affected by infections, and that a balanced and bountiful diet may tend to produce such crops.

DISCUSSION:

There is gypsum in Activator One and Activator Two, and we only add more if the compost is getting very wet.

I am mystified by what is meant by Brown Disease, but if we get it on synthetics we suffer very little.

BUILDINGS FOR MUSHROOM GROWING

S. A. F. SAMPSON
Sampson Mushrooms Ltd.

This is a very large subject, and it would be quite impossible to deal with it in detail in the time available. I have been wondering how to make this time interesting and, I hope, useful.

The only reason that I am here is apparently that, according to the powers that be, we had recently completed a building programme successfully when doubling the size of the Plant. This must apply to quite a few of you. However, it was suggested that my talk should be on our experiences over this expansion.

The general problems relating to buildings have been dealt with extremely well, and at length, in many of the leading books written on Mushroom Growing. As you may remember these books usually deal with it under the headings of:—Site, Lay-out, Size and Shape of Buildings, and Building Materials.

At this stage, I should like to make clear a point which, no doubt, quite a number of you do know, and that is that my plant is on the tray system, and in building up the plant I have tried to follow as closely as possible, and in every way, the work and teaching of Drs. Sinden and Hauser—I owe to them a tremendous debt of gratitude. In fact, it would not be an exaggeration to say that without their work I should not be here to-day as a Mushroom Grower.

Now, as regards the expansion, we had to consider very carefully whether to extend the existing site or to move lock, stock and barrel. We considered this, not only in relation to the general problems relating to the site, but also because in the Autumn of 1955 I had a very serious set back through ' la France ' and Dr. Sinden warned that careful thought should be given as to whether, or not, to enlarge on this existing site.

From the general points of view the plant was well situated for a good train service to the London Markets, but not so good for the Midlands. However, an important point, the climate was pretty good. Being near the sea it was cooler in the hot spells than some of the inland parts of the country and also more humid than many parts of the country.

As regards the disease angle, we waited until well on with the Summer of 1956 for signs of the recurrence of ' la France,' but as none appeared, we decided to go ahead with the programme. All the plans had been made, Town and Country Planning permission had been obtained, and the Builder had been fully briefed regarding the strict time schedule for completion of various buildings. This had been most carefully worked out and planned so as to avoid any dislocation of our weekly laying programme.

Naturally, with this expansion, considerable thought had to be given to lay-out, but before this, of course, we had to decide how big

the new plant should be? We figured it out like this—five men were needed as a minimum for certain operations and we were trying to design a plant which would give these five men full employment, with the help of some mechanical aids, such as a Compost Turner, Stacker Trucks, Roller Conveyor, Spawning and Casing Machine and Soil Mixer, etc.

Incidentally, although hardly concerning Buildings, but nevertheless of general interest, as regards the Spawning and Casing Machine, we did hope to have one on show at the Mechanical Handling Exhibition; however, owing to delays in transport and custom formalities it has only got as far as Folkestone. Many of you may have seen it working at Messrs. A. G. Linfield Ltd. last year. It was developed some years ago by Drs. Sinden and Hauser for the purpose of mixing Spawn intimately through the compost, thereby giving increased yields. In connection with this trials have shown that heavier spawning is an advantage.

It was considered that we should be able to lay, at least, 3,000 square feet of bed a week which meant that the new weekly unit would be two of the old existing Cropping Houses, or one of the new proposed Houses. One thing to be sure of in planning the lay-out was to allow enough room to use the mechanical aids. In order to obtain this, obviously, the new Heat Rooms and Spawn-running Rooms, Spawning Corridor, Soil Shed and Packing Shed had to be sited in the most advantageous position, and this necessitated being bold and pulling down a good many of the existing Buildings.

However, here it may interest you to see a plan of the Farm, as it was, and one of how it is now that the Buildings have been completed. Here, on the old plan, we have the manure yard, the Soil Shed, the Garage, the three Heat and/or Spawn-running Rooms and the Packing Shed, the Boiler House and the ten Cropping Houses.

Here, on the new plan, you will see that it was decided to pull down all those Buildings which have been shaded.

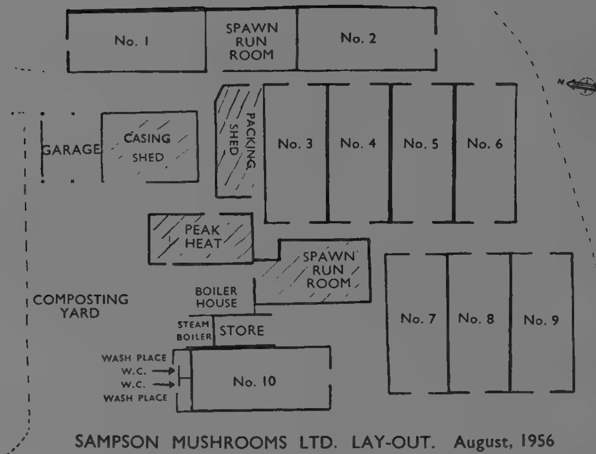
In point of fact, all that were left were the ten Cropping Houses and the Boiler House. The new scheme was to have ten growing units as before. Thé Heat Room was sited so that it could be filled direct from the Compost Yard and on either side of the Heat Room the Spawn Growing Rooms were situated.

Here, on the opposite side of the manure yard, is the Spawning Corridor and then here, when emptying the Spawn-running Rooms, the trays run through and on to the Soil Shed, where they are cased and then are taken on to the Cropping Houses.

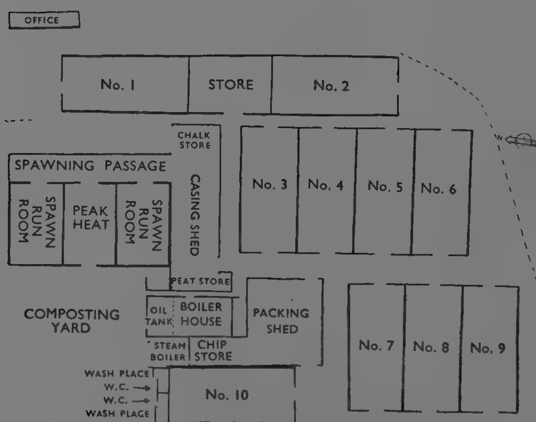
The new Packing Shed is situated right in the middle of the Plant and, also as you will see, the Boiler House is happily, conveniently situated.

As regards the Boiler, while increasing the size of it, it was changed over to oil.

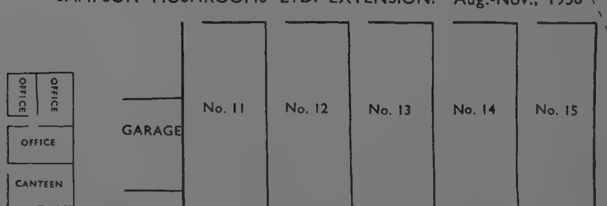
Also the Offices and Canteen are here.



SAMPSON MUSHROOMS LTD. LAY-OUT. August, 1956



SAMPSON MUSHROOMS LTD. EXTENSION. Aug.-Nov., 1956



For this larger expansion we felt it would be an advantage to use a large local Builder, capable of putting plenty of labour on to the job and, consequently, really sticking to the programme for the completion of the buildings which had been laid down for him. This paid off handsomely in the end, as although the buildings cost more (and that, perhaps, is a very moot point), they were earning money at the earliest possible moment.

Another point here, well worth mentioning, is the advantage of employing, either a good Architect, or, as in our case, a first-class Quantity Surveyor, who was extremely interested in this extraordinary(!) business of Mushroom Growing, and the special problems that governed the type of building to be erected. His advice was invaluable on checking on the Builder's itemised quotes, on the different types of materials under consideration, their insulation properties and durability under our difficult conditions, together with their cost. Also, from his experience, he was able to put us right on one or two errors in structural features which, subsequently, would have cost a lot of money.

Another valuable, and worthwhile, adviser is a Heating Engineer. It is much more complicated than it appears to get a good equal distribution of heat all round the plant.

Before starting out on this building project, a lot of preliminary work on investigating the various types of buildings available was done and a lot of help was obtained from various books of reference. In particular, the Building Research Station's Book on the Thermal Insulation of Buildings has, amongst other useful things, a comparison table of materials giving:—Method of Application, the price, the Standard Size and the " U " value, etc. Another booklet of great use was the Institution of Heating and Ventilating Engineers which contained Tables of Thermal Conductivity, etc.

Our Quantity Surveyor also produced some very useful drawings on the different types of wall construction, giving their " U " values and other such factors. These and some of the books can be seen here afterwards. If anybody doesn't understand " U " values I certainly don't blame them, but I would advise you, before considering new materials, that it is worth reading up how to calculate " U " values as it does give a method of comparing the insulation properties of one material against another. If I tried to explain it now I should obviously get in a muddle and, probably, you would forget it even if I didn't. It is much better to mug it up just before you really want to use the knowledge—which is what I did.

Also a lot of help was obtained from various firms who were approached regarding their different materials, some of these were biassed in describing the merits of their own product, although, in fairness, I am sure it is very difficult for any firm to realise the very severe conditions that are to be experienced in Heat Rooms, Spawn-running Rooms and even Cropping Houses.

We decided, wherever possible, to try in a simple way and test the materials for ourselves. One simple thing we did was to knock a hole in the old Heat Room wall and, in this, put the bricks or the insulating

board, or whatever it might be, and test it for moisture by weighing it before and after peat-heat, and, also, of course, it gave us some idea how the material would stand up to the job. The tests were carried out on each material several times using different surface paints or renderings to keep out moisture. The tests were very simple, but they did give us a lead.

Another thing, as regards ceiling insulation for the Heat Rooms, different thicknesses of various materials were tried, such as aluminium foil, glass wool, etc., and temperature readings were taken by just placing thermometers on the top of these materials.

In ascertaining which of these materials to use the Grower, himself, must decide to draw the line at where the cost outweighs the merit of the material. As regards our own Heat Rooms it was felt that expense should be no object, as this Building plays such a vital part in our cultural technique.

With this Building, we finally decided upon placing the one Heat Room in between the two Spawn Running Rooms to obtain better insulation for the Heat Room. The walls surrounding the Heat Room are made up of a double row of hollow four inch foam slag blocks with a two inch cavity. The walls of the two Spawn Running Rooms are made up of a double wall—the outside being hollow clay pots, the inside being hollow foam slag blocks. The inside walls of all these Rooms receive two coats of Synthaprufe paint. The great problem here is, of course, to be able to vapour-proof these walls, not just waterproof them.

Vapour-proofing is a very difficult thing to achieve, particularly in the Heat Room it is essential as one must keep the moisture from penetrating the walls and spoiling the insulation materials. Very nearly every insulation material relies on the air pockets within it to give the insulation and, except for one material, I know of no other that moisture does not spoil its qualities.

Anyway, for the Heat Room we finished off by painting two coats of a silver metal paint with a final $\frac{1}{8}''$ screed of graphite paste. The ceiling was made up of asbestos bedded into a thick paste and nailed tight against the rafters and/or wooden battens. This, of course, was also treated as for the walls. Over the top of the asbestos was left a cavity and then stretched wire mesh on which was placed 8—12″ of loose bagged glass wool, which is inspected from time to time.

As regards the Growing Houses, the advantages and disadvantages of a flat roof, against gable roofs, were investigated pretty thoroughly, and, although, possibly, the flat roof is a little cheaper in construction, the gable roof, with a ceiling, does give the chance to get in and inspect the insulation material and to add more if necessary.

As regards the walls the insulation was required here to be good enough to ensure that, under all conditions, the condense point or dew point was in the wall and not in the room. The walls of this block were again double, the outer one being of the hollow clay pots and the inner one being of foam slag solid blocks with a carefully checked two inch cavity.

DISCUSSION:

In our new cropping houses we have four pipes either side of the ducting. We can get one or all eight of them on. They are 1½-inch pipes, and we use hot water and a circulating pump.

The cavities in the heat-room walls are not filled. The insides of the walls are cement rendered, with a waterproofing agent in the rendering; then Synthaprufe, two coats of vapour-proof aluminium paint; and, to finish off, a screed of graphite paste.

In the heat room we use steam for an hour or two just to move the temperature upwards. We don't use it again until very nearly the end of the process. Then we force up the temperature to 140° F. purely as a hygiene measure.

Details are given in *Meded.* 33, *Wageningen Institute*, Holland, of the design of thermostatically-controlled electric **soil heaters** consisting of a transformer and wire netting. The heaters provide an even distribution of heat, cause little drying-up of the soil, have a working life of 3-8 years, are easily moved and are not dangerous.

Agricultural & Horticultural Engineering Abstracts No. 1/58.

A £10-a-week minimum **wage demand** for Britain's 600,000 farmworkers is on the provisional agenda for the National Union of Agricultural Workers' Conference in May.

Daily Express, February 8/58.

In general, plants with a high **sugar content** are more resistant to viruses, and conditions such as low light intensity, high nitrogen feeding and high night temperatures will tend to reduce sugar content, said Dr. I. W. Selman, of Wye College.

Commercial Grower, February 7/58.

THE NEW MUSHROOM UNIT AT FAIRFIELD

G. F. SHEARD

Director, Fairfield Experimental Horticulture Station

MR. G. F. SHEARD

The mushroom unit at Fairfield is now almost ready for action and it was felt that members of the MGA might be interested in the design and construction of the sheds.

When we were considering the project in its initial stages our main aim was to provide houses with good insulation at a reasonable cost. To this end we tried to assess the merits of three possible types of construction:—

1. Purpose built sheds using reinforced concrete "Portal" frames and purlins, roofed with corrugated asbestos sheeting and lined with asbestos insulating board. The design of these sheds was very good but they were ruled out by the high cost for only moderate insulation.

2. Moulded asbestos cement sheet huts set on dwarf brick walls and lined with asbestos insulating board. These were attractive in price and had moderately good insulation but were discounted due to the difficulty in constructing them in multiple units with valley gutters and the restriction in head room caused by curvature or cranking at the sides.

3. Architect designed houses using timber "Portal" frames, roofed in asbestos and lined with a combination of glass fibre and asbestos insulating board. The design was prepared by our Regional Architect and was adapted from some rhubarb forcing sheds he had erected at Stockbridge House Experimental Station where the requirements were similar to those we had specified for mushrooms. This type was finally selected as giving a well designed building with very good insulation at a moderate cost.

The Table below gives the relative cost and the comparative insulation values for the three types. The cost figures allow for all building work but exclude drainage, electricity and heating.

	Type 1	Type 2	Type 3
Relative cost	155	100	120
U value for Roof	0·61	0·41	0·18
U value for Walls	0·30	0·47	0·25

The unit we have constructed consists of two cropping sheds each 40ft x 18ft internal measurement and an open sided manure composting shed of the same dimensions. The three spans are built together with valley gutters and we have made provision to complete the unit by adding

a third cropping shed at some future date. The sheds measure $7\frac{1}{2}$ feet to the eaves and 12 feet to the ridge. The following are the main constructional details of interest:—

1. Framework

The principles are provided by timber "Portal" frames based on designs for rigid frame farm buildings published by the Timber Development Association and spaced to give 10ft bays. We have used this design in other buildings on the Station and it is attractive in both design and cost. A rigid timber frame costs about half that of a steel truss and two thirds that of reinforced concrete. Provided the timber is pressure treated with a preservative they should have an indefinite life and require little or no maintenance. The absence of a cross tie at eaves level is of a great advantage in giving good headroom without excessive height at the eaves.

2. Walls

These are constructed in 11 inch cavity brickwork, the cavity being filled with glass fibre at a density of 3-4lb./cu. ft.

3. Roof

The roof has an inner lining of asbestos insulating board secured to timber bearers. The upper surface of this lining is covered with polythene sheeting the edges of which are heat welded to provide an overall vapour seal. A 1 inch bitumen bonded glass fibre blanket is then fixed over the purlins and the roof completed by covering with corrugated asbestos cement sheeting.

4. Floors

The floors are set on 9 inches of hardcore blended with ashes and consist of 3 inch of no-fines concrete topped with 1 inch of granolithic screed whilst still green. The purpose of the no-fines concrete is to improve insulation and reduce heat loss through the floors.

5. Ventilation

Ventilation is provided by four hopper vents at floor level and by three 6 inch ridge extractors in each shed. There is little published information on the ventilation requirement of the mushroom crop. Edwards[2] suggests a minimum requirement of one change per hour. According to the manufacturers performance data supplied, the three extractors should provide between one and four air changes per hour according to weather conditions. I feel our ventilation may be inadequate but we have provision to fit extractor fans in each gable if necessary.

6. Heating

We have a steam service joining the site and propose to use this for heating and as a source of live steam for peak heating. To begin with we shall use a system of low level heating pipes with quick coupling main connections so that we can alter the pipe position and number at will.

7. Cropping

In the first instance we propose to use a tray system as this lends itself to experimental work with plots. The sheds are, however, so arranged that we can use shelves as an alternative in one or both spans.

To begin experimental work we first propose to carry out calibration trials to assess likely variations from factors other than those under investigation and then to carry out experiments on casing materials similar to those started at Stockbridge.

References.

1. HUDSON, A. ROSCOE, " T.D.A. Rigid Frame Farm Buildings." Timber Development Association, 21, College Hill, London, E.C.4. Reprinted from *Wood*, July, 1955.
2. EDWARDS, R. L., " The Mushroom and its Environment " Scientific Horticulture Volume XII, 1955-56, pp. 83-89.

1. Roof framing to take insulated lining ; outside cavity wall shows Fibreglass filling.

2. T.D.A. rigid frames. Roof frames with asbestos insulating board and polythene lining partly fitted.

3. Similar to 2, but showing more clearly the polythene vapour seal.

4. Fibreglass roof insulation and corrugated top sheeting in position.

CASING EXPERIMENTS AT STOCKBRIDGE HOUSE

F. G. SMITH, Director, and A. J. BEDDING
Stockbridge House Experimental Horticulture Station

Mr. F. G. SMITH

The facilities for mushroom growing at Stockbridge House Experimental Horticulture Station, near Selby, Yorkshire, are at present limited to four experimental rhubarb forcing sheds, each with a ground area of 30ft x 45ft. The sheds have 9 inch brick walls and well insulated roofs. As their primary purpose is forcing rhubarb they have earth floors and no provision is made for ventilation.

For the purpose of growing mushrooms, one of the exterior double doors has been replaced by a false door to which a fan is fitted. The fan extracts air from the sheds which is replaced through a door at the other end of the shed, opening into a corridor. Although this amount of ventilation would not appear to be quite adequate enough considering the size of the sheds, no ill effects on the crop have been seen. This is probably due to the fact that as only ground beds have been used up to the present time, there is a potentially very large volume of air in the sheds compared to a limited bed area. However, as it is hoped to make more use of the space in the sheds by the introduction of trays, improved methods of ventilation are to be tried. Recently two of the sheds have each been fitted with four roof ventilators, and it is possible that trials will be made on the effects of passing air into the sheds by means of ducts made up of large diameter perforated polythene tubing.

Composting is done in the open air on a concrete standing, but the heaps are surrounded by straw bales in order to minimise the drying and chilling effects of cold winds. Up till now all composting has been done by hand, but it is intended that mechanical means will be introduced so that the process can be made as uniform as possible.

Satisfactory peak heating in the sheds is obtained by the use of pipe heat, boosted up by the injection of free steam.

So far two experiments have been conducted in these sheds on the use of different casing materials. The first experiment, using synthetic compost made from wheat straw and MRA activators, was laid down in April. The experiment consisted of a comparison between soil and two types of peat: one was granulated sedge peat described as of selected grade and originating from the Somerset Moors, the other a granulated sphagnum moss peat of local origin from Thorne.

The soil was a calcarious clay sub-soil from a site over-lying lime excavations in the Skipton area; it was of a very suitable texture for

casing as it retained its structure under watering and did not pan. These three materials were used in both the sterilised and unsterilised state. The peats were combined with two grades of chalk on a 50:50 dry weight basis; one with lumps passing through $\frac{3}{4}$ inch riddle but not $\frac{1}{4}$ inch, and the second $\frac{1}{4}$ inch to dust. All combinations of these treatments were used.

Although the crop as a whole was quite satisfactory no treatments proved outstanding. Yields from all plots were close, varying between $1\frac{1}{2}$ lb. to 2lb. per sq. ft., and in addition the standard error of the experiment was high, meaning that there was a large unexplained variation of crop from plot to plot, quite independent of the casing treatments.

Two minor points emerged, the first being that an appreciable amount of disease appeared on the unsterilised casings, particularly the soil, and secondly that the steam sterilisation of the peats certainly appeared to have no depressing effect on the crop.

During the course of this first experiment it was noticed that guard bays surrounding the experiment appeared to give a very heavy crop. They had been cased with a mixture of sterilised moss peat and fine chalk which had been mixed 6 months previously and stored in sacks.

This observation led to the second experiment which was a comparison of old mixtures of peat and chalk with those freshly mixed. The compost was prepared from stable manure and laid down in June—again both sedge and sphagnum peats were used in conjunction with lump and fine chalk. No mixtures of longer than 6 weeks standing were available, and although again the whole experiment is cropping very satisfactorily, the early indications are that no particular treatments are outstanding.

There are, however, two main differences between these mixtures and the original mixtures of long standing. One is the difference in length of time between 6 weeks and 6 months that the mixtures were allowed to stand before use, and the second is that in the original mixture the peat had been sterilised, and therefore might have been in a damper condition and more likely to react with the chalk than mixtures used in the second experiment.

So far it would appear that the plot to plot variation in the second experiment, where the compost used was made from stable manure, will be less than in the first experiment where a synthetic compost was used. One of our difficulties may therefore be the production of uniform composts, a problem we hope to solve by the use of suitable machinery as stated earlier on.

It is hoped that the final analysis of the second experiment will be available before the Conference, but it is unlikely that either of these experiments can be relied upon to give information of value to the commercial grower, and it is only when consistent results are available from a number of experiments, carried out under varied conditions, that

the information gained from them can be put forward as a firm recommendation of commercial value.

Because of the difficulties we have experienced in carrying out experiments on mushroom beds on earth floors, we are now turning our interests to the possibilities of using either timber or metal trays for mushroom growing, and observation studies on the use of these trays have commenced.

A third experiment has also been started with the object of finding out means of reducing the large inexplicable variations which have turned up between beds independent of treatments applied, as it is clear that until such variations can be overcome it will not be possible to detect the smaller differences between plots due to treatments applied.

In brief, these early experiments have emphasised the problems which confront those who wish to experiment with mushrooms.

DISCUSSION:

We started off by comparing peat mixtures and soil, at the suggestion of the MGA. We are prepared to try anything generally considered to be of interest, such as Vermiculite perhaps.

We are growing in houses which are used for rhubarb forcing from November to March, so unfortunately we lack continuity.

With certain reservations, I think spent mushroom compost compares very favourably indeed with farmyard manure for a number of other crops. By and large it is a good source of organic matter.

WHAT IS BROWN DISEASE ?

Dr. I. F. STOREY
Regional Plant Pathologist—NAAS, Derby

During the autumn of 1956 a disorder of mushrooms occurred on several farms in the East Midland Province which was unlike anything I had come across before. Furthermore, the trouble was present and causing considerable losses on a farm where " La France " had been identified by Dr. Sinden some years ago. Most people who had seen the earlier outbreak agreed that if it was not identical with the earlier one, the present trouble was similar to it in many respects.

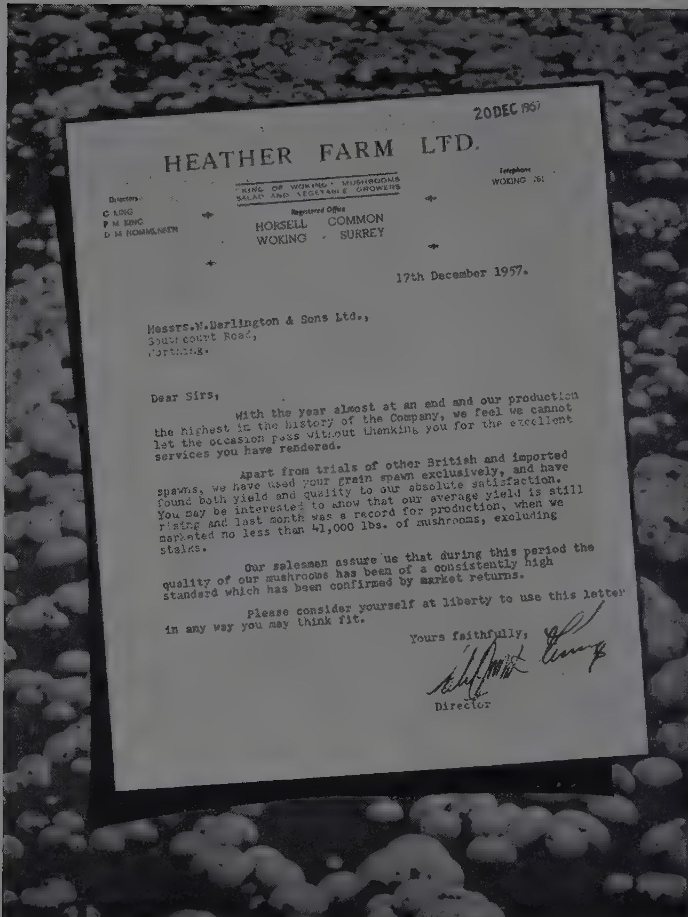
The prospect of coming face to face with the mysterious " La France " and learning something more about it was not to be despised—and so we set to work to find out what we could about it. I should like to associate two of my colleagues with what I have to say: Dr. L. Ogilvie at Bristol who has been investigating similar outbreaks in the South Western Region and Mr. E. Lester at Shardlow who has done much of the work which I shall describe to-day. Dr. Ogilvie, working along rather different lines in Bristol to what we have done, has reached similar conclusions and I feel that this is very encouraging.

The present trouble is distinct from the disorder known as " Mummy Disease," a very characteristic condition which can be readily transmitted by taking compost and casing soil from affected beds and placing them in healthy beds. After 3-4 weeks the characteristic symptoms appear in the previously unaffected beds. At the moment there is no known cause—but such evidence as we have does not suggest that a virus disease is responsible.

Characteristics of Brown Stem Disease.

This disorder is seen in its most typical form on shelf beds where the very characteristic patches of affected mushrooms can be seen. The one feature which is common to all mushrooms is the presence of water-soaked streaks in the internal tissue of the stipe of the young sporophore. These streaks become visible later as translucent areas in the flesh of the stipe extending from the base to the pileus. The flesh of the pileus may be mottled pink especially near the junction with the stipe and immediately above the gills. No normal mushrooms were found on any of the three holdings—all those examined exhibiting the symptoms described above to some degree, even the youngest buttons and the healthiest mature mushrooms were of a poor dull colour and in most instances rather small.

On the Yorkshire holding where the crop is grown on shelf beds, patches occurred which were devoid of crop, and around which were mushrooms that had died before picking. Careful examination of the patches revealed an apparent gradation of the disorder increasing in intensity towards the centre. All the apparently normal mushrooms exhibited watery stipe with a band, about a foot wide, of mushrooms



20 DEC 1957

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17th December 1957.

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Dear Sirs,

With the year almost at an end and our production the highest in the history of the Company, we feel we cannot let the occasion pass without thanking you for the excellent services you have rendered.

Apart from trials of other British and imported spawns, we have used your grain spawn exclusively, and have found both yield and quality to our absolute satisfaction. You may be interested to know that our average yield is still rising and last month was a record for production, when we marketed no less than 41,000 lbs. of mushrooms, excluding stalks.

Our salesmen assure us that during this period the quality of our mushrooms has been of a consistently high standard which has been confirmed by market returns.

Please consider yourself at liberty to use this letter in any way you may think fit.

Yours faithfully,

Director

which were more severely affected at the edge of the patch. Within the band, most of the mushrooms were dead, having succumbed almost at maturity on the outside edge, and at a progressively earlier stage down to the " buttons " at the inside edge. There was a gradation from this zone to one in which the casing material was heavily invaded with mycelium which supported masses of pin heads which were dead. Finally towards the centre of the patch there was an area with little or no growth in the casing material. This sequence was found on other holdings but was less clear cut as the crops were being grown in trays and extensive bacterial infection was present.

Isolation from severely affected mushrooms from the Leicestershire holdings repeatedly produced bacteria which have since been identified as *Pseudomonas tolaasi*—the cause of Brown Blotch. Mildly affected mushrooms from all three holdings have failed to produce any bacteria and it is concluded that this Brown Blotch infection was secondary, but its constant appearance in the worst areas is of interest and perhaps not without significance.

As a next step, spawns were prepared from affected mushrooms and grown on grain which was used to spawn peak-heated compost in plant pots or glass jars. Casing was done using a peat mixture and normal mushrooms were later produced from spawn prepared from affected mushrooms.

A similar result to the above was obtained when badly affected trays were taken and the casing soil removed and recased with either soil or peat mixture. Up to ½ lb. per sq. ft. of good mushrooms were obtained from some of the worst affected trays we could find. In addition casing material and compost from these trays failed to reproduce the disease when placed in normal trays just starting to produce mushrooms.

Extracts were prepared from the diseased mushrooms and a portion was Seitz-filtered to act as a control. The extracts were watered on to young developing buttons, a proportion of which were pricked with a sterile needle after treating with the extract. The treated area was then covered with a bell jar for 48 hours. Brown Blotch developed on the mushrooms treated with the unsterilized filtrate but no sign of the brown stem condition was seen in any of the mushrooms treated with these extracts.

We have been unable to prove by any of the means used that this condition of the mushroom is due to an infectious agent present in the spawn, casing soil or compost.

Features of Cropping on Farm where Brown Stem was Troublesome.

At this stage we were fortunate to be able to examine the cropping records for the past 5-6 years from a farm where the disease was severe and some interesting information was obtained.

1. The trouble is particularly liable to occur in the autumn and during the winter months, and on this particular holding the worst months for crop yields were August, September and October.

2. If one crop showed signs of the trouble then one would expect to find signs of the trouble in other crops in production at that time. The youngest crop usually showed the most severe effects whilst the older ones showed the trouble at a progressively later stage. This suggests that some adverse factor was operating at a specific time during the life of the beds.
3. At the time the trouble was at its worst, in October last year, its occurrence was widespread, and apart from spawns the only factors common to all farms was probably the weather and the use of peat as a casing material. In all houses at each centre the run of spawn was all that could be desired.

From the evidence available we suggest that the trouble is liable to occur when spells of warm humid weather make evaporation of water from the beds difficult. Such conditions of high humidity are liable to occur during the autumn and the constant association of the disorder with Brown Blotch would also point to an excessive degree of wetness persisting on the surface of the beds.

How far the trouble can be overcome by more adequate air changes or movement remains to be seen, but on some holdings visited during the winter no trouble was seen. On the holding in question the ventilation system depended entirely on fans, and velometer measurements indicated that approximately 1-2 changes of air per hour were being obtained. Under conditions of high humidity this would appear to be inadequate for the normal development of the mushroom. Under the drier air conditions of June a better production was obtained and very much less Brown Stem. *Positive evidence that a great reduction in the amount of trouble can be achieved by attention to air conditions was obtained on one nursery where very severe trouble was being experienced.* As soon as cropping was switched to a house fitted with ducting and fans the disorder disappeared and the yield of mushrooms increased very considerably. In addition the quality was very much improved.

During periods of high atmospheric humidity conditions arise which are unfavourable for the proper development of the mushroom, particularly where peat is used as a casing material and where there is a vigorous spawn run. The trouble can be overcome by attention to air conditions, but at this stage it is impossible to suggest how far air movement as distinct from air change is effective in bringing this about. The recent work of Plunkett at Birkbeck College in London may be significant in this connection and he suggests that transpirational water loss may be an important factor affecting fruit body formation of certain Agarics. The effect of moving the air may be achieving this as well as removing undesirable chemical products. In addition there may be much more sense in the practice of dropping the temperature of the beds before watering and raising it afterwards than we have realised.

Recently, using mushrooms grown in 10 inch clay plant pots with peat as casing material, we have tried to reproduce the brown stem condition by varying the watering treatment and evaporation from the

surface of the peat. We did this by watering some pots every day and others on alternate days. Half the pots in each series were covered with plastic sheeting but this was left open near the base of the pot.

The disorder was reproduced and brown stem was very much more severe in the batch which was watered every day and covered with plastic sheeting than in any of the other treatments. Thus in some measure we have been able to confirm the suggestion as to the cause made from an examination of crop records.

L. Ogilvie and B. B. Till have been making similar observations in the South West and especially in the Bristol area during 1956 and '57. There Brown Stem may cause much loss from November to March. It is always worse in poorly ventilated houses, and especially in the lower trays.

A room at the NAAS laboratories at Bristol was devoted to mushroom culture, using various composts and casing soils, " diseased " and otherwise obtained, from growers. There was no correlation between the use of 'short' and 'long' composts or various kinds of casing soils and the incidence of Brown Stem. Again, Brown Stem could not be induced by the use of composts obtained from growers consistently troubled with the " disease " or of composts obtained from " diseased " houses.

At one time it was thought that ammonia was the cause of the symptoms, since somewhat similar, though more intense, symptoms could be induced by subjecting the mushrooms to ammonia vapour, but chemical analyses of composts, casing soils, and mushrooms failed to indicate any consistent difference in the amounts of ammonia in good and bad.

Again, attempts were made to infect mushrooms growing in glass jars in the laboratory, by means of chopped up pieces and extracts of mushrooms affected with ' Brown Stem,' but without success.

The water relationships of the mushroom were then considered. The distribution of ' diseased ' mushrooms in the commercial houses seemed to be correlated with wetness. The small experimental mushroom house at the NAAS Centre, Bristol, was devoted to simple watering experiments. Four large mushroom trays were well watered every day with a known volume of water, and four trays of identical compost and casing soil were watered only when it appeared necessary. Brown Stem developed overwhelmingly in the overwatered trays whereas no trouble was seen on the normally watered trays. Symptoms of Brown Stem also developed in mushrooms grown in glass jars, which has been subjected to excess of water.

This work is now being extended to cover both ventilation and watering.

In conclusion I should like to make a suggestion. At least three disorders of the mushroom have been described in recent years—La France, Stoller's disorder and the one we are dealing with to-day—and I very much suspect that they are all due to one and the same cause. Whether " damping off " is the same I am not prepared to say but, for at least three of the four, improved ventilation has been suggested as a control measure.

FUTURE POLICY will be discussed at the adjourned Annual Meeting in London on Thursday afternoon, 17th April. Please be at Agriculture House, Knightsbridge, at 2.30 p.m.

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